UTILIZATION OF FLY ASH FOR THE MANAGEMENT OF ROOT-KNOT NEMATODES ON SOME VEGETABLE CROPS

ABSTRACT

OF THE

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

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IRAM

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ABSTRACT

Studies were undertaken to manage the root-knot nematodes by the application of fly ash on three major vegetable crops of India. Fly ash is a major particulate air pollutant in India. The annual production is about 120 MT. For experiments, fresh fly ash was collected from Thermal Power Plant, Kasimpur, U.P., India. In the present research, it was tried to evaluate its potential against the root-knot nematodes for successful cultivation of vegetable crops. Two most common and frequently occurred species of root-knot nematodes (*M. incognita* and *M. javanica*) were selected for all the experiments. The highly susceptible cultivars of three important vegetables (okra cv. Long Green, cucumber cv. Poona Kheera and pepper cv. Suryamukhi Green) were taken for the study. The study was divided into three major sections.

SECTION-I

In this section, incidence, frequency and intensity of root-knot disease and the identity of species of *Meloidogyne* associated with vegetable crops in 5 districts of Western Uttar Pradesh (Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar) were undertaken. Highest incidence and intensity of root-knot disease was found in the vegetable fields of Aligarh district followed by Bulandshahr, Ghaziabad, Mahamaya Nagar and Gautam Buddha Nagar. Similarly, incidence and intensity of disease was also determined vegetable-wise. Highest incidence and intensity were noticed on eggplant

followed by tomato, okra, pepper, cucumber and cabbage. Three species- *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in the area. Of the three identified species, *M. incognita* and *M. javanica* were more common and frequent than *M. arenaria*. Disease intensity in terms of gall index (GI) and egg mass index (EMI) was maximum in case of *M. incognita* and minimum in *M. arenaria*. The survey indicates that root-knot nematodes would affect the plant growth and can cause appreciable yield losses to vegetables, if suitable measurement step will not be taken.

Another experiment was conducted to analyze the physico-chemical properties of various levels of fly ash amended soil (0, 5, 10, 20, 30, 40, 50, 75 and 100%). The pH, EC, CEC, WHC, sulphate, chloride, phosphorus and potassium were increased in all the levels of fly ash and maximum increase was observed at 100% fly ash level. While nitrogen content was gradually decreased as the level of fly ash was increased.

SECTION-II

Eight different concentrations of fly ash-extract (5, 10, 20, 30, 40, 50, 75 and 100%) were tested against hatching and mortality of root-knot nematodes. All the levels of fly ash-extract significantly suppressed the hatching of *M. incognita* and *M. javanica* juveniles. Inhibition (%) in hatching of juveniles was directly proportional to the levels of fly ash-extract. As the level of fly ash increased, inhibition in hatching of both the juveniles was also increased. Similarly, all the levels of fly ash-extract

were harmful to juveniles of both the nematodes. All the above levels of fly ash-extract killed the juveniles of both the nematodes. The mortality (%) was directly proportional to concentration as well as number of days increased. However, inhibition (%) in hatching and mortality (%) of juveniles was greater in *M. javanica* as compared to *M. incognita.*

Penetration of juveniles was retarded at all the levels of fly ash in roots of all the three crops (okra, cucumber and pepper). Penetration of the juveniles of both the nematodes was inversely proportional to the fly ash ratio. As the levels of the fly ash were increased, less number of juveniles of *M. incognita* and *M. javanica* were penetrated. Similarly, development of juveniles of both the nematodes was delayed and suppressed at all the levels of fly ash. At last, in fourth week none of the juveniles reached to mature female stage except at 5-10% fly ash levels. However, effect of fly ash was slightly more on *M. javanica* than *M. incognita.*

SECTION-III

Soil application of fly ash was found beneficial to all the three crops (okra. cucumber and pepper). All parameters were increased significantly up to 30% levels of fly ash, maximum being at 20% level in all the crops. Nematode inoculated plants also showed improvement in their plant growth, yield and photosynthetic pigments under the influence of fly ash. However, in combined treatments all parameters were increased significantly from 10 to 30% levels, highest being at 20% level

+ nematode combination. While at 40% level, all the parameters were at par in single fly ash amended treatment or in combination with any nematode, on any crop. In rest of the combinations, nematodes effects were suppressed completely. So from 50 to 100% fly ash amended soil + nematode showed similar results as single fly ash amended treatments, however growth was slightly less than fly ash amended soil without nematode.

At the same time, development of galls, egg masses and reproduction were completely checked. Fly ash and nematodes together interacted antagonistically. The study showed that fly ash was best to the plant growth and productivity at lower level (20%) and toxic to root-knot nematodes at all the levels. The beneficial level of fly ash in all parameters for all the three crops can be arranged as follows- **20%** > 30% > 10% > 5% > C > 40% > 50% > 75% > 100%. The beneficial effect of fly ash + nematodes combination can be arranged as follows- **20%** > 30% > 10% > uninoculated control > 5% > 40% > 50% > 75% > 100% > inoculated control.

Best dose of fly ash (20%) together with different inoculum levels of nematodes (250; 500; 1,000; 2,500; 5,000 and 10,000), affected variably to growth, yield and photosynthetic pigments of all the three crops. All parameters were significantly decreased as the inoculum level increased. All parameters were found highest with best dose and low inoculum level (20% fly ash + 250 N) compared to control set. However,

this dose was effective enough to kill the nematodes except in plant inoculated with highest level (10,000), where some individuals of root knot nematodes were able to slightly affect the plant growth, yield and photosynthetic pigments. However, none of the galls or egg mass was produced. So, it can be summarized that 20% fly ash is the best dose for these crops. Because this dose is increasing the growth of plants and also managing the root-knot nematodes.

From the present study it appeared that all the levels of fly ash were harmful for hatching, penetration and development of juveniles of both the nematodes - *M. incognita* and *M. javanica*. At the same time the soil application of fly ash was beneficial for all the three crops and most suitable level was found 20%. This level (20%) can be recommended for the management of root-knot nematodes in the vegetable fields. The use of fly ash in the agricultural fields will improve the fertility of soil and on the other hand it will control the nematodes. The disposal problem of huge amount of fly ash will also be solved.

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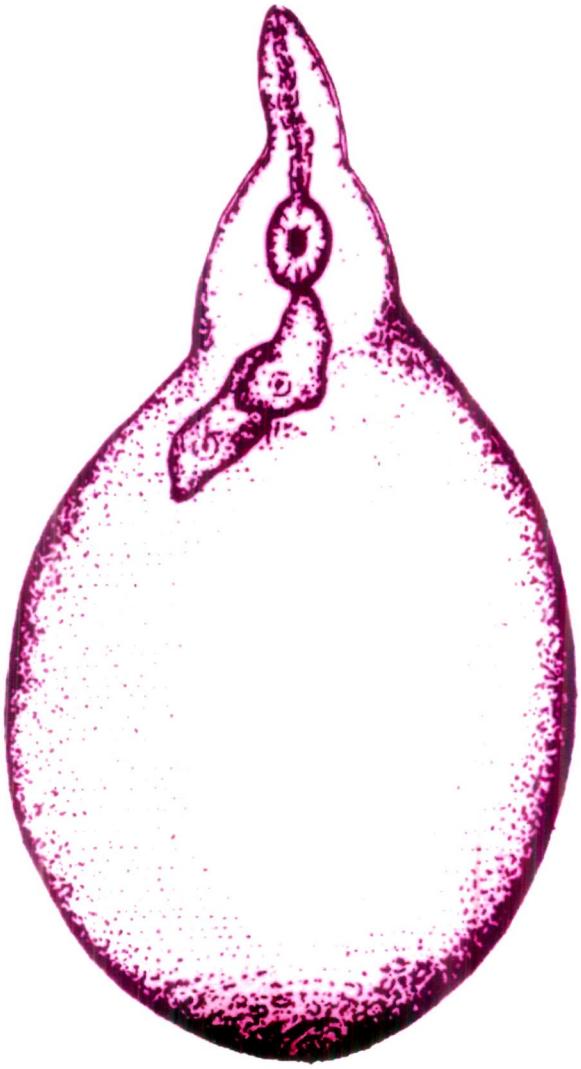

Dedicated to

My

Beloved Parents

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Certificate

This is to certify that the thesis entitled **"Utilization of fly ash for the management of root-knot nematodes on some vegetable crops"** is an original and bonafide research work carried out by **Ms. Iram,** under my guidance and supervision. She is allowed to submit her thesis to Aligarh Muslim University, Aligarh for the award of the degree of **Doctor of Philosophy in Botany.**

(Dr. Abrar Ahmad Khan)
Research Supervisor

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*In the name of **'Almighty God'** the great artisan and sustainer, who's will alone let's nature work and make things possible. His benevolence alone which provided me enough zeal to complete this **Thesis**.*

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Finally, with all faith in the ***Almighty*** *I place this work in the hands of my examiner with hope that he will bear with the shortcomings that might have crept into this thesis inadvertently.*

Iram

(IRAM)

CONTENTS

LIST OF TABLES

32. Effect of different levels of fly ash on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

33. Effect of different levels of fly ash and *M. incognita* (5000 juveniles) on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

34. Effect of different levels of fly ash and *M. javanica* (5000 juveniles) on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

35. Effect of fly ash on disease intensity and reproduction factor of *M. incognita* and *M. javanica* (5000 juveniles) on pepper cv. Suryamukhi Green.

36. Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of okra cv. Long Green.

37. Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of okra cv. Long Green.

38. Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of cucumber cv. Poona Kheera.

39. Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of cucumber cv. Poona Kheera.

40. Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

41. Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

LIST OF FIGURES

INTRODUCTION

Fly ash is the major particulate waste in India, generated in Thermal Power Plants, during the coal combustion. About 87 Thermal Power Plants in the country are coal based which produce around 100 million tons of fly ash per year. Because, Indian coal contains 30-40% fly ash (Kumar *et al.*, 2000). Hence, disposal of such a huge quantity of generated fly ash is a serious problem. As remedial measures for this problem, different applications of fly ash are promoted, viz. using fly ash for preparing concrete bricks, using in road preparation and using a soil conditioner in agriculture. In fact, fly ash consists of practically all the elements present in soil except nitrogen (Adriano *et al.*, 1980). Hence, fly ash has a vast potential for use in agriculture as an amendment, especially due to its physical condition, which are conducive for plant growth, as well as due to the presence of macro and micro nutrients in it. Many researches have explored the potential of fly ash in agriculture (Wong and Wong, 1986, 1989; Raghav and Khan, 2002; Rizvi and Khan, 2009). It has been found beneficial for the growth of many plants (Mishra and Shukla, 1986; Singh, 1989; Pasha *et al.*, 1990; Khan and Khan, 1996; Raghav and Khan, 2002; Rizvi and Khan, 2009).

Root-knot nematodes, *Meloidogyne* spp. are distributed worldwide and are economically important plant pathogens of global significance. They are found more frequently and in greater numbers in areas with warm or hot climates and short or mild winters. There are about 90

species at present in this genus. Four species, *M. incognita* (Kofoid and White) Chitwood, *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood and *M. hapla* Chitwood are recognized as major species, as they are most common and damaging (Taylor *et al.*, 1982). These four species constitutes about 95% of the total *Meloidogyne* population (Sasser and Carter, 1982). Vegetables are considered as their most preferred group of host crops. They are attacked by one or other species of root-knot nematodes. The attacked crops suffer both quantitatively and qualitatively. In areas where root knot nematodes are not controlled, they cause damage to be about 25% (Khan, 1988) with damage in individual fields ranging as high as 60% (Sasser, 1980; Sasser and Carter, 1982).

Eleven species of root-knot nematodes, namely *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, *M. hapla*, *M. graminicola*, *M. bravicauda*, *M. Africana*, *M. exigua*, *M. graminis*, *M. lucknowica* and *M. tritocoryzae* have been recorded from 29 states of India (Sitaramaiah, 1984; Nayak *et al.*, 1986; Khan and Khan, 1990; Gaur *et al.*, 1993). However, *M. incognita* with four races (Race 1, Race 2, Race 3, Race 4), *M. javanica* with two races (Race 1, Race 2), *M. arenaria* with one race (Race 2) and *M. hapla* are major pest of vegetable crops in the country (Khan, 1988; Khan and Khan, 1991a; Khan *et al.*, 2003). More than 50% vegetable fields have been found infested with root-knot nematodes in Uttar Pradesh (Khan and Khan, 1996; Khan, 2007).

Our country has achieved self sufficiency and a good degree of stability of food production. Vegetables form the most important component of a balanced diet. The country is the world's second largest producer of vegetables next only to china. However, our per capita production is still quite low. They suffer due to root-knot disease caused by *Meloidogyne* species particularly *M. incognita* and *M. javanica* almost through out the country (Khan and Khan, 1990; 1991a; Khan *et al.*, 2003). Alleviation of these nematodes is necessary for successful cultivation of vegetables. Biological and other eco-friendly control measures are now in progress. However, none of the eco-friendly control measures is satisfactorily in application, since chemicals have been banned.

Recently, fly ash has shown its inhibitory effect on root-knot nematodes (Tarannum *et al.*, 2001; Rizvi, 2008) but for making generalization sufficient information is not available. Therefore, its potential against the root-knot nematodes is needed to test. In the present study it was planned to evaluate the fly ash potential to manage the root-knot nematodes on three important vegetable crops of India i.e. okra, cucumber and pepper.

The thesis was divided into three sections, the main aspects of each section were as follows:

SECTION-I

1. Survey, collection and identification of root-knot nematodes species.
2. Maintenance and raising the population in pure form separately.
3. Collection and analysis of fly ash and soil for their compositions.

SECTION-II

4. Observation of fly ash-extract on hatching and mortality of *M. incognita* and *M. javanica* juveniles.
5. Observation of fly ash amended soil impact on penetration of *M. incognita* and *M. javanica* juveniles in okra, cucumber and pepper roots.
6. Observation of fly ash amended soil impact on developmental stages of *M. incognita* and *M. javanica* juveniles in okra, cucumber and pepper roots.

SECTION-III

7. Observation of effect of different fly ash levels on plant growth, yield and photosynthetic pigments of okra, cucumber and pepper.
8. Observation of effect of different fly ash levels with *M. incognita* or *M. javanica* on plant growth, yield and photosynthetic pigments of okra, cucumber and pepper.

9. Observation of effect of 20% fly ash with different inoculum levels of *M. incognita* or *M. javanica* on plant growth, yield and photosynthetic pigments of okra, cucumber and pepper.

Review of Literature

REVIEW OF LITERATURE

FLY ASH

Fly ash left after combustion of coal in the power generation units accounts about 100 million tons in the environment annually in India. It is likely to exceed 120 million tons by the year 2020 AD (Anonymous, 1997). Presently, there are about 87 coal-fired power plants in operation in India. Burning of 202.75 million tons coal in these power plants results in production of 2.2 thousand tons of coal-ash per day (based on information gathered from the site http/www. cea.nic in/opt 7 vidut chap 4 htme on 26 Sept. 2002). High ash content in Indian coal and inefficient combustion technologies account for a high ash production (Mishra and Shukla, 1986). Between 85-95% of the ash is generated in the form of bottom ash, which is carried to nearby ash ponds through large diameter pipes in the form of slurry. The remaining 5-15% goes to stack and is trapped in the precipitators, is fitted. However, considerable amount (10-15%) escapes from the stack and is, subsequently, deposited over a large area, falling on the soil and vegetation. The size of area so affected by coal-ash depends upon the burning temperature of coal, height of stack and wind velocity etc. (Khan and Khan, 1996).

Properties of Fly Ash

The physical, chemical and mineralogical properties of fly ash depend on composition of the coal burnt, combustion condition, efficiency and type of emission, control devices and the disposal methods

used (Van Hook, 1979; Adriano *et al.,* 1980). Fly ash consists of many minute, glass like particles of 0.01 to 100 mm having specific gravity 2.1 to 2.6 (Davison *et al.,* 1974). It gives spherical, glassy and transparent appearance due to melting of silicate minerals during coal combustion (Hodgson and Holliday, 1966). Fly ash of Indian coal consists of 25% sand sized particles (2 to 0.02 mm), 65% silt sized particles (0.02 to 0.002 mm) and 10% clay sized particles (<0.002 mm) (Mishra and Shukla, 1986). It contains various useful elements such as Ca, Mg, Fe, Cu, Zn, K, Mn, B, S and P along with some heavy metals (Majumdar and Mukherjee, 1983; Fulekar *et al.,* 1983; Dalmau *et al.,* 1990; Sikka *et al.,* 1994) except nitrogen (Adriano *et al.,* 1980). The fly ash is generally alkaline, with pH mostly ranging from 8.2 to 12.5 (Furr *et al.,* 1977; Raghav, 2006). The contents of B, Ca, Mg, Mn and Mo in plants grown on fly ash or fly ash amendments indicate that these nutrients are present in a soluble form (Cope, 1962; Hodgson and Holliday, 1966; Upadhyay, 2002; Raghav, 2006). Deposition of fly ash on land affects the soil properties. Soil becomes rich with salts and trace elements, thus reduces bulk density of soil and ultimately increases pH, electrical conductivity, water holding capacity, Ca, Mg, Na, B and $So4^{-2}$ in the soil. Townsend and Hodgson (1973) observed that the bulk density of fly ash of British coal ashes was quite low i.e. 0.99 to 1.73 g cm^{-3}. Mishra and Shukla (1986) compared the fly ash with soil. They studied particle size distribution in which silt was greater in amount in the fly ash while bulk density was less than the soil. Electrical conductivity, pH and nutrients

were in high amounts in fly ash compared to soil. Deshmukh *et al.* (2000) when applied graded levels of fly ash, bulk density was decreased while water holding capacity of soil was increased. The available NPK, micro-nutrients like Cu, Fe, Zn, Mn and exchangeable Ca and Mg were increased with fly ash application. The effect was non-significant on pH, EC and lime content and significant effect on CEC. Similarly, Khan *et al.* (1997) observed that the porosity, water holding capacity, CEC and conductivity were higher in fly ash. Sulphate, carbonate, bicarbonate and chloride contents and concentrations of P, K, Ca, Mg, Mn, Cu and Zn were also higher in fly ash than in field soil. But N was present in low amount in fly ash.

Sims *et al.* (1995) studied adsorption and disadsorption of phosphorus in soil amended with various concentrations (0-30%) of fly ash. Fly ash increased soil phosphorus from 13-34 mg/Kg (20-30% fly ash) which enhanced plant growth. Kukier *et al.* (1994) tested two fly ashes from Georgia as a source of boron for corn growth on two soils of different textures. Both soils (Cecil and lake land soil) showed a linear relationship between fly ash rates and hot water extractable soil boron which increased with decreasing pH. Lee *et al.* (2002) reported that the mixture of coal and gypsum increased the uptake of silicate and phosphate and the amount of exchangeable calcium in the soil. It was concluded that the coal ash and gypsum mixture could be a good alternative to inorganic soil amendments to restore the soil nutrient balance in paddy soil.

Effect of Fly Ash on Plants

Fly ash application alters the physico-chemical properties of soil, which affects the growth, development and productivity of plants. Since fly ash has all the micro and macro-nutrient elements, it is now used as non-conventional fertilizer for the improvement of plant growth and yield. Singh and Singh (1986a) studied the response of rice cv. Madhuri to different levels of fly ash application at varying fertility levels in saline soil. Fly ash at 20% level significantly increased the contents of NPK at all growth stages and uptake of these nutrients by grain and straw. The biomass production of two grasses (*Agrostris tenuis* and *Festuca arundinacea*) and legume (*Lespedeza cuneata*) was 5-30 times higher in fly ash amended plots (Fail, 1987). Wong and Wong (1989) found that seed germination of *Brassica parachinensis* and *B. chinensis* was enhanced in sandy soil added with 3 to 6% fly ash. Pasha *et al.* (1990) also observed that soil amendment with fly ash (10% and 20%) improved plant growth, yield and chlorophyll contents of leaves of cucumber plants. Kene *et al.* (1991) added fly ash in the soil at the rates of 0,5,10 and 15% (w/w). They found that the application of fly ash at 10 t/ha gave the best results in sunflower. Shrivastava *et al.* (1993) observed the effect of soil amendments with varying levels of fly ash on growth and pigments contents of *Lactuca sativa*. Results indicated that application of fly ash in low concentration promoted growth, dry matter production and photosynthetic pigments. Soybean plants grown in 25% and 50% fly ash showed significant improvement in plant growth, yield, leaf pigment,

protein and oil contents of seeds (Singh, 1993; Singh *et al.,* 1994). Singh *et al.* (1994) studied that plant growth, yield and sugar content of *Beta vulgaris* plants were improved at low fly ash level. Matte and Kene (1995) evaluated the effect of different levels (0, 5, 10 and 15 tons/hectare) of fly ash on Kharif crops (cotton, green gram, groundnut, mustard, sorghum and soybean). Lower levels were found beneficial for the crop. Sajwan (1995) used sewage sludge and fly ash mixtures in ratios (4:1, 4:2, 4:3 and 4:4) and application rate to soil was 0, 50, 100, 150, 200 and 400 tons/acre. Plant growth and yield improved at 50-100 tons/acre. Srivastava *et al.* (1995) studied the effect of soil amendment with varying levels of fly ash on growth and pigment content of *Lactuca sativa.* A marked increase in growth was noticed in plants grown in 10% fly ash-soil mixture. Higher doses (20-30%) caused a definite suppression of growth. Pigment contents followed the same trend. Results indicated that application of fly ash in low concentration promoted growth, dry matter production and photosynthetic pigments. Ash treatments of 30, 40 and 50 Kg ha^{-1} increased the bean dry matter yield over control by 49, 57 and 64% respectively (Krejsl and Scanlon, 1996). Khan and Khan (1996) reported that fly ash addition to soil resulted in luxuriant growth, bigger and greener leaves, improved plant growth and yield (flowering, fruiting, fruit weight/plant, mean fruit weight) of tomato. Carotenoids and chlorophyll were also enhanced from 40 to 80% being optimal at 50%. Scotti *et al.* (1996) studied the effect of fly ash on Chicory (*Cichorum intybus*) grown in two soils with or without fly ash (3% and 10%).

Addition of 3% fly ash showed a significant increase in yield. Karpate and Choudhry (1997) studied the effect of fly ash on *Triticum aestivum* var. Kalyan Sona. Plants were either irrigated with 25, 50, 75 and 100% fly ash water or grown in 50, 70 and 90% fly ash amended soil. At lower concentrations of fly ash water and fly ash had stimulating effect on the crop. However, at higher concentrations, the treatment showed a deleterious effect. Tripathy and Sahu (1997) found that 50% fly ash applied to soil increased height, girth, leaf number, leaf area, spike length and dry weight of wheat plant. In another study, Wong and Su (1997) reported that addition of fly ash improved seedling emergence and dry weight, yield of *Agropyron elongatum*. Ten tons of fly ash per hectare was found to be the best rate for improving soil properties (Kuchanwar *et al.,* 1997). Masilamani and Dharmalingam (1999) observed the germination behaviour of teak (*Tectona grendis)* drupes in coal ash incorporated medium. A mixture of sand and coal ash mixed with nursery medium increased the germination and seedling behaviour/vigour but coal ash alone inhibited the seed germination and seedling behaviour/vigour. Kumar *et al.* (1999) reported an enhanced yield of rice, grown in 4% and 8% coal ash amended soil. Results suggested that 4% coal ash addition resulted in higher grain yield of rice without any possible trace metal contamination of soil or plant. Sahu and Dwivedi (1999) showed that seed germination in *Vigna munga* and *Abelmoschus esculentus* was highest at 25% level of fly ash, while the plant growth was at 50% concentration in *V. mungo*, whereas it was maximum at 25%

in *A. esculentus* plant. Malewar *et al.* (1999) observed that fly ash: soil ratio of 1:1 increased the number of leaves and number of branches above control values in tomato and spinach but 1:3 ratios promoted dry matter in both crops. Khan and Ghadirpour (1999) examined relative efficacy of broadcast, row and spot treatment of fly ash on the growth and yield of chilli, eggplant and tomato. Row application of fly ash @ 3 Qt/ha significantly increased the plant growth and yield of tomato cultivars.

Singh *et al.* (2000) conducted a series of studies on growing mulberry (*Morus alba*) plants in 25 earthen pots in five different sets of fly ash/soil composition including control (i.e. fly ash/ soil- 25:75, 35:65, 50:50 and 75:25). After obtaining the data for various growth parameters, it was observed that the 25:75 of fly ash/soil ratio was viable for sustaining the growth of *Morus alba* plants. Bhaisare *et al.* (2000) conducted an experiment during summer 1993-1994 on green gram (K-851) with three levels of N (0, 18.75, 25 kg/ha) and P (0, 37.8, 50 kg/ha) and four levels of fly ash (0, 5, 10 and 15 t/ha) on vertisol. Results showed that significantly highest content and uptake of nutrients were recorded with the increasing levels of fly ash upto 10 t/ha. Further increase in its application did not show any advantage. The highest contents of crude protein and test weight were also recorded at the same level of fly ash. Amongst the fertilizers, green gram responded well to higher doses of N and P fertilizers for yield, quality and nutrient uptake. Grewal *et al.* (2001) showed that application of coal-ash to soil increased both grain and straw yield of pearl millet (direct) and wheat (residual) at

all levels of coal-ash application (5, 10 and 20%). Khan *et al.* (2001) observed the effect of fly ash concentrations of 0, 5, 10, 20, 30 and 35% g Kg^{-1} on seed germination, growth and metal uptake by barley and wheat plants. The beneficial effects were observed at 20 and 30% g Kg^{-1}. Khan and Abdussalam (2001) worked on winter ornamental plants viz. *Acrolinium roseum, Brachycome idesidifolia, Dimorphotheca sinuate, Linum usitatissimum, Calendula officinalis, Papaver rhoeas, Tagetes patula, Helichrysum bracteatum, Tropaeolum majus* and *Salvia officinalis* in soil amended with varying levels of fly ash (0, 25, 50, 75 and 100%). The *Acrolinium, Salvia* and *Papaver* showed positive response to certain levels of fly ash treatments. Karmakar *et al.* (2001) demonstrated that the application of paper factory sludge with coal ash enhanced grain and straw yields of wheat in 3.6 and 3.3% respectively than those grown with farmyard manure. Khan and Singh (2001) observed that row application of fly ash @ 3 Qt ha^{-1} significantly increased the plant growth and yield of tomato. Raghav and Khan (2002) applied fly ash to soil in different ratios for the improvement of growth and yield of tomato. It was observed that all the lower ratios (5, 10, 20 and 25%) significantly increased the plant growth and yield compared to control. Recently Rizvi and Khan (2009) reported that lower levels of fly ash were beneficial to plant growth at eggplant.

. Fly ash also contains some toxic substances along with heavy metals in appreciable amount which affect to plants. Several studies showed that application of fly ash to soil is not toxic to plant if applied in

particular proportions but it showed adverse effect at higher levels. Satyanarayana *et al.* (1988) reported that higher ambient level of fly ash decreased shoot growth and leaf pigments of *Datura innoxia*. Singh (1989) observed inhibition in seed germination and post emergence mortality in seedlings of chickpea and lentil in fly ash amended soil. Inhibition in root nodulation was also found at higher levels. He suggested that heavy metals present in fly ash might have caused suppressed growth. Mcmurphy *et al.* (1996) noticed that fly ash caused alteration in the maize genome, when plants were grown in soil mixed with fly ash. It also reduced the soil genotoxic effects. Sahi and Singh (1996) showed that heavy metals present in fly ash caused genetic damage to *Allium cepa* which led to death. Gupta *et al.* (2000) found that higher levels of fly ash exhibited reduced growth of nodulation, chlorophyll, carotenoid, protein contents and nitrate reductase activity, and the elements Fe, Zn, Cu and Mn were accumulated in large quantities in plants. Fly ash has deleterious effects on plant growth and yield if it is used in more than 50% levels (Khan and Khan, 1996; Raghav *et al.*, 2003).

Fly ash contains very small amount of nitrogen. Plant growth, yield, leaf pigments and seed proteins are affected adversely through poor nitrogen availability in fly ash amended soils (Wong and Wong 1986, 1989). Garau *et al.* (1991) reported that net nitrogen mineralization decreased as the rate of fly ash application increased. However, the effect of fly ash on nitrogen mineralization was also dependent on its

composition. The application of 50 t/ha fly ash did not significantly affect nitrogen mineralization. Singh (1993) observed that root nodulation and leaf nitrogen gradually decreased with an increase in the fly ash concentration from 60% level. Sikka and Kansal (1995) found that yield of rice was increased significantly at 2–4% w/w due to input of N, S and Fe from fly ash, while it was reduced at 8% fly ash level due to lower P and Zn availability and possible toxicities of other elements.

ROOT-KNOT NEMATODES

Root-knot nematodes (*Meloidogyne* species) constitute a major group of plant-pathogenic nematodes affecting crop production and substantially reducing food quality. Almost all of the plants that account for majority of the world's food supply are susceptible to this group of pathogens (Sasser *et al.,* 1982; Taylor *et al.,* 1982). They are parasitic of all the major food crops, vegetables, plantation crops, fruits and ornamental plants grown in all the agro-ecological or climatic zones of the world. Especially the vegetables are the most preferred group of host crops. They are attacked by all the 4 major species of root-knot nematodes viz., *M. incognita, M. javanica, M. arenaria* and *M. hapla.* In areas where root-knot nematodes are not controlled average crop yield losses are estimated to be about 25 percent with damage in individual field ranging as high as 60 percent (Sasser, 1980; Sasser and Carter, 1982).

Historical Background

Root-knot nematode was first recognized by Berkeley (1855) in England. Since then the pathogen has been designated for a considerably long period of time with different names (Sasser and Carter, 1982; Triantaphyllou, 1982; Hirshmann, 1985). The present day name *Meloidogyne* was given by Goeldi (1887). Chitwood (1949) on the basis of morphological differences, particularly in the cuticular markings of the perineal region of adult females, described four species viz. *Meloidogyne incognita* (Kofoid and White,1919) Chitwood, 1949; *M. javanica* (Treub,1885) Chitwood, 1949; *M. arenaria* (Neal,1889) Chitwood, 1949 and *M. hapla* Chitwood, 1949. Since then, from time to time new species were discovered, described and added to the species list of the genus. So far, 90 species of *Meloidogyne* have been reported (Khan *et al.*, 2005).

International Importance

In view of International importance of root-knot nematodes, an International *Meloidogyne* Project (IMP) funded by USAID was started under the leadership of Prof. J. N. Sasser in 1975 at North Carolina State University at Raleigh (USA), to investigate the various aspects of *Meloidogyne* problem on worldwide basis. With the cooperation of nearly 100 nematologists from 70 countries of the world, investigations on root-knot nematodes were carried out under the aegis of IMP till its termination in 1984. The Project achieved its main objectives in identifying the species and races of *Meloidogyne* causing damage to

various crops in different parts of the world. Four species Viz. *M. incognita, M. javanica, M. arenaria* and *M. hapla* were recognized as major species of international importance. These species comprised about 95% of the total *Meloidogyne* populations of the world (Sasser and Carter, 1982). Later, in 1984 a new replacement of project called Crop Nematode Research & Control Project (CNRCP) was started at Raleigh to look for the suitable and effective measures of control to solve the root-knot problems. This project was terminated in 1989. However, none suitable control measures except chemicals could be suggested. But due to pollution hazards with chemicals, now several management strategies have been suggested in recent years.

National Importance

In India, work on distribution and identification of different species and races of *Meloidogyne* were started very late in 1983 in cooperation with the International *Meloidogyne* Project at eight centres, Aligarh (Prof. S.K. Saxena, Prof. M. W. Khan), Banglaore (Prof. K. Krishnappa, Prof. K. G. H. Setty). Hissar (Prof. D. S. Bhatti), Jaipur (Prof. P.C. Trivedi), Nasik (Prof. A. B. Pawar), New Delhi (Prof. C. L. Sethi), Orissa (Prof. Y. S. Rao) and Udaipur (Prof. B. S. Yadav). First phase on identification of species and races of root-knot nematodes in the country were completed in 1990s. So far, eleven species of root-knot nematode, namely, *Meloidogyne incognita, M. javanica, M. arenaria, M. hapla, M. graminicola, M. bravicauda, M. africana, M. exigua, M. graminis, M.*

lucknowica and *M. tritocoryzae* were recorded from different states of India (Sitaramaiah, 1984; Krishnappa, 1985; Nayak *et al.*, 1986; Khan, 1988; Gaur *et al.*, 1993). However, *M. incognita* with four races (Race 1, Race 2, Race 3, Race 4), *M. javanica* with two races (Race 1, Race 2), *M. arenaria* with one race (Race2) and *M. hapla* were recognized major pests of vegetable crops, and *M. graminicola* as a dominant species on rice in the country (Sitaramaiah, 1984; Krishnappa, 1985; Khan and Khan, 1990; Khan *et al.*, 2003). The second phase on control of nematodes through nematicides and chemicals was completed in last decade of the previous century (1990–2000). In recent years, now work on various aspects of root-knot nematodes, especially on management through integrated pest management (IPM) excluding chemicals are in progress at different centres of the country.

Status in Uttar Pradesh

Uttar Pradesh is a most populous state of India covering a large area. Substantial work on various aspects of root-knot nematodes has been done at Aligarh, Pantanagar, Allahabad, Jhansi, Faizabad, Kanpur and Lucknow centres of Uttar Pradesh. A number of systematic surveys were conducted in vegetable fields of different districts of Uttar Pradesh to observe the pattern of the distribution and to identify the species and races of root-knot nematodes. So far 5 species of root-knot nematodes, *M. incognita, M. javanica, M. arenaria, M. lucknowica* and *M. graminicola* have been reported to exist in the state. (Khan, 1969; Singh, 1969;

Sitaramaiah and Vishwakarma, 1978; Mathur and Varaprasad, 1978; Siddique *et al.*, 1986; Haidar, 1989; Khan and Khan, 1990; Khan *et al.*, 1984, 1993, 1994; Khan, 1997). Of the species recorded to occur in the state, *M. incognita, M. javanica and M. arenaria* are more common than other species. *M. incognita* and *M. javanica* have been reported on a large number of host plants (Sitaramaiah and Vishwakarma, 1978; Mathur and Varaprasad, 1978; Prakash, 1983; Khan *et al.*, 1984; Haidar and Khan, 1986; Khan and Khan, 1985; 1990; Verma, 1987; Khan *et al.*, 1987, 1993, 1994; Khan *et al.*, 2003). Singh (1969) described *M. lucknowica* from Lucknow which was found infecting sponge gourd, *Luffa cylindrica* from the area. *M. graminicola* was found on *Cyperus rotundus* and *Dactyloctenum aegyptium* in Hardwaganj of Aligarh district (Siddique *et al.*, 1986). A recent study conducted in eleven districts of Eastern U.P. shows that *M. incognita* and *M. javanica*, followed by *M. arenaria* are common in root-knot nematode populations of the area (Khan, 1994; Khan *et al.*, 2003). In some districts, *M. incognita* is more prevalent than *M. javanica* while in others *M. javanica* dominates over *M. incognita.* The species of root-knot nematodes present in the state according to their relative occurrence can be arranged in the following order as *M. incognita* > *M. javanica* > *M. arenaria* > *M. graminicola* > *M. lucknowica*. The species were found either singly or in mixed populations. In single population, *M. incognita* was most frequently encountered in all the districts. Mixed population of *M. incognita* and *M. javanica* was more common in the districts than other combinations.

Although differentiation of races in the species of root-knot nematodes was started very late in Uttar Pradesh, the races in *M. incognita* (Race 1, Race 2, Race 3, Race 4) and *M. arenaria* (Race 2) have been reported (Khan, 1988; Khan and Khan, 1991a; Khan, 1997). Recently Khan, (1997) and Khan *et al.* (2003) recognized races of *M. javanica* (Race1, Race 2) in Uttar Pradesh.

Vegetable crops like eggplant, tomato, cauliflower, cabbage, pepper, okra, broad bean (*Vicia faba* L.), cucumber, musk melon (*Cucumis melo* L.), water melon (*Citrullus lunatus*), Pumpkin (*Cucurbita moschata*, Duch), squash (*C. maxima*), bittergourd (*Memordica charantia* L.), spongegourd, spinach, parwal (*Trichosanthes dioica* Roxb.), bean (*Phaseolus vulgaris* l.), kundru (*Coccinia indica*), soybean (*Glycine max* (L.) Merr.), lectuca (*Lectuca sativa* L.) etc. suffer greatly due to root-knot disease in several districts of Uttar Pradesh, especially in western districts of Uttar Pradesh. *M. incognita* and *M. javanica* are the most dominant species in the districts. Among the races, *M. incognita* Race 1 is a most occurring race. Nearly 50% of vegetable fields were found infested. Several management measures for root-knot nematodes were evaluated at Lucknow, Kanpur, Jhansi, Pantanagar, Allahabad and especially at Aligarh centres in the state.

Effect of Fly Ash on Root-Knot Nematodes

The fly ash has shown its influence on plant diseases caused by biotic pathogens. Addition of fly ash in soil alters physico-chemical

characteristics of soil that directly influences activity of soil microorganism. Effect of soil application of fly ash on a few soil borne pathogens including nematodes have been examined. Khan (1989) observed that fly ash amended soil decreased the root penetration of juveniles of *M. incognita* and root-knot disease intensity on tomato. Singh (1989) obtained similar response of galling and egg mass production by *M. incognita* on lentil. Singh (1993) reported that higher concentration of fly ah suppressed root-nodule bacteria (*Bradyrhizobium japonicum*) and root-knot nematode (*Meloidogyne javanica*) to a great extent. At 100% fly ash, none female or juveniles or egg mass of *M. javanica* was recovered. The harmful effects of fly ash on *M. incognita* and *M. javanica* have been observed on okra, tomato and pea plants (Khan and Khan, 1994; Singh *et al.,* 1994). Higher levels (100%) completely checked development of nematode and was injurious to plant growth as well. Fly ash incorporation in soil (20-100%) adversely affected the root invasion by the larvae and decreased the disease intensity (galls/root system) and reproduction (egg mass/root system) of root-knot nematodes, *Meloidogyne* species on cowpea and tomato (Khan *et al.,* 1993, 1997).

Joshi *et al.* (2000) observed the effect of organic amendment and fly ash on root-knot disease of tomato. The root galling index was reduced greatly. Tarannum *et al.* (2001) studied the different levels of fly ash (0, 25, 50, 75 and 100%) on hatching, penetration and development of *M. javanica* juveniles on chickpea. The hatching and penetration were suppressed greatly. At lower levels (25 and 50%) of mixture low number

of J2 developed to the mature female stage. Siddique and Singh (2005) observed the effect of fly ash (0, 20 and 40% with soil), *Pseudomonas striata* and root nodule bacterium- *Rhizobium* spp. on the reproduction of *M. incognita* and on the growth and transpiration of pea plant, both in the presence and absence of nematode. The addition of 20 and 40% of fly ash with soil was beneficial for plant growth both in nematode inoculated and uninoculated plants. The use of 20% fly ash increased galling and nematode multiplication compared to plants grown without fly ash, while 40% fly ash had an adverse effect on galling and nematode multiplication. Iram (2006) studied the response of root-knot nematode, *M. incognita* Race 1 to fly ash on pepper (*Capsicum annuum* L.). All the fly ash levels reduced the hatching and suppressed the development of juveniles but increased the mortality rate. Root penetration was found inversely proportion to fly ash ratios. Highest increase in plant growth was observed at 20% level. Azam *et al.* (2007) observed the effect of *M. incognita* on ivy guard (*Coccinia cordifolia*), number of galls and egg masses per plant were decreased in 10 to 50% fly ash levels as compared to control. Recently, Rizvi (2008) found that different levels of fly ash were toxic in killing the juvenules of *M. javanica* and suppressed the hatching and penetration, and their subsequent development was delayed. However, fly ash was beneficial for the growth of eggplant, *Solanum melongena* at lower levels, i.e. 20%.

OKRA [*Abelmoschus esculentus* (L.) Moen.]

The okra is commonly known as Lady's finger or bhindi. The plant is considered to be of African or Asian in origin. An annual, erect herb, 0.9-2.1 m in height, covered with hair, is cultivated as a garden crop or mixed field crop throughout India. Leaves are cordate, palmately 3-5 lobed, coarsely toothed, flowers yellow with a crimson centre; capsules, also called pods, 12.5-30.0 cm long, pyramidal, oblong (horn-like), green or creamy green, with longitudinal ridges, smooth or hairy; seeds many rounded, striate, hairy. Bhindi is grown as a garden crop or home yard plant throughout the tropical and sub-tropical parts of the world. It is found under cultivation throughout India, up to an altitude of 1,200m, but is seldom cultivated as a field crop, it can be cultivated on any type of soil but does best on well-manured loam soils. Two crops are usually raised in a year, one sown in the beginning of the summer or during Feb–March and harvested from April to June; and the other sown with the onset of rains or during June–July and harvested from August to October. The plants start flowering after 40 days of sowing in the early varieties, and 50-60 days or more in the mid season varieties.

The tender pods are used as a vegetable. They are eaten boiled or in the form of sliced and fried pieces. They are also used for thickening soups and gravies because of their high mucilage content. Sometimes they are sliced and sun dried for off-season use. In West Africa, the flowers are eaten in soups. The tender leaves are sometimes boiled and

eaten as spinach. The ripe seeds are roasted and used as a substitute for coffee. They are also used as curries and chutneys. The seeds are rich in protein (18-26%). It is a fair source of calcium, iron and vitamins.

Root galls due to infestation with root-knot nematodes, *M. incognita* acrita, *M. hapla, M. arenaria* and *M. javanica* are observed on the bhindi (okra) plants. The plants become sickly and bear reduced number of fruits. The nematode is responsible for 28 to 91 per cent loss in okra fruit yield where the infestation is too high in the field (Bhatti and Jain, 1977; Reddy, 1986; Sheela and Nair, 1986; Khan, 1988; Khan and Khan, 1990).

CUCUMBER (*Cucumis sativus* L.)

Cucumber originated in India. Large genetic variety of cucumber has been observed in different parts of India. It has been cultivated for at least 3,000 years in Western Asia, and was probably introduced to other parts of Europe by the Romans. Records of cucumber cultivation appear in France in the 9^{th} century, England in the 14^{th} century, and in North America by the mid 16^{th} century. From India, it spread to Greece and Italy and later into China. The cucumber is a creeping vine that roots in the ground and grows up trellises or other supporting frames, wrapping around ribbing with thin, spiraling tendrils. The plant has large leaves that form a canopy over the fruit. The fruit is roughly cylindrical, elongated, with spread ends, and may be as large as 60 cm long and 10 cm in diameter. Cucumber at the home garden level can be raised by the

polyhouse cultivation method. The fruit is ready for harvest in 3 months. In summer months, it is best to allow it to spread on the field while it is giving fruit but in the rainy season a support should be made to put the creeper on it.

Cucumber grown to be eaten fresh (called slicers) and those intended for pickling (called picklers) are similar. Cucumbers are mainly eaten in the unripe green form. The ripe yellow form normally becomes too bitter and sour. Having an enclosed seed and developing from a flower, cucumbers are scientifically classified as fruits. Much like tomatoes and squash, however their sour-bitter flavour contributes to cucumber being perceived, prepared and eaten as vegetables still "Vegetable" is a purely culinary term, and there is no conflict in classifying cucumber as both a fruit and a vegetable. Colour can vary from creamy yellow to pale or dark green. The cucumber is a natural diuretic which is used in the fitness world by body builders and people trying to reduce their weight.

Cucumber was the first crop, on which the root-knot disease was recognized by Berkely (1855) in England. This crop is one of the most vulnerable crops to the attack of root-knot nematodes and causing root galls. Salam and Khan (1988) observed heavy root galling on this crop in Andman and Nicobar Islands. Khan (1988) and Pasha *et al.* (1990) observed heavy losses in cucumber due *to M. incognita, M. javanica* and *M. arenaria* in Uttar Pradesh.

PEPPER (*Capsicum annuum* L.)

The chilli is commonly called as red pepper. It is a native of tropical America and now cultivated throughout the world. In India, it was introduced in 17th century and is now grown in all parts covering about 733,800 hectares. Plants are herbaceous or semi-woody annual or perennial. The leaves are ovate, tapering to a sharp point, entire up to 15cm long, dark green on the upper surface and pale on lower surface. The flowers are small, white and borne singly or in clusters of 2 or 3 in the exils of the leaves. The fruits are of diverse shapes and sizes depending upon the variety. The chilli is generally transplanted. The winter crop is planted from July to September and summer crop from February to March. The crop is ready for harvesting in about 3 months after planting.

Pepper is an important cash crop in India and is grown for its pungent fruits, which are used both green and ripe (the latter in the dried form) to import pungency to the food. As a condiment, it has become indispensable in every Indian home. It is also used medicinally, and in chutnies and pickles. The pungency is due to the active principle 'Capsicin' contained in the skin and the septa of the fruit.

Among root-knot nematodes, *M. incognita* attacks pepper, wherever, it is grown and reduces its yield, more acutely in dry season irrigated land than in land cropped only during the wet season. Several pepper cultivars are highly susceptible to *M. incognita* (Khan and Khan,

1990). Crop losses caused by this nematode increase to such an extent that a considerable amount of research is directed towards developing resistant or at least tolerant pepper cultivars (Khan and Khan, 1991b). However, control of nematode is relative to the intensity of disease and satisfactory economic control may not be achieved by any single practice prevalent in agricultural tracks.

Materials and Methods

MATERIALS AND METHODS

For the present study, different materials and methods were employed. The thesis work was divided into three major sections in the following manners:

SECTION-I

This section deals with collection, identification and maintenance of root-knot nematodes as well as collection and analysis of fly ash and soil for their compositions.

Experiment 1

Collection and Identification of Root-Knot Nematodes

Surveys were conducted for the collection of root samples of vegetables infected with root-knot nematodes in five districts (Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar) of Western Uttar Pradesh, India (Fig. 1). Fields with vegetable cultivation in 4-5 localities in each district were visited and infected root samples were collected in polythene bags and brought to laboratory. Species of root-knot nematodes were identified on the basis of perineal pattern and confirmed by North Carolina Host Differential Tests. Incidence, intensity of disease, frequency of occurrence of different species on different vegetable crops in localities of each district were calculated as follows:

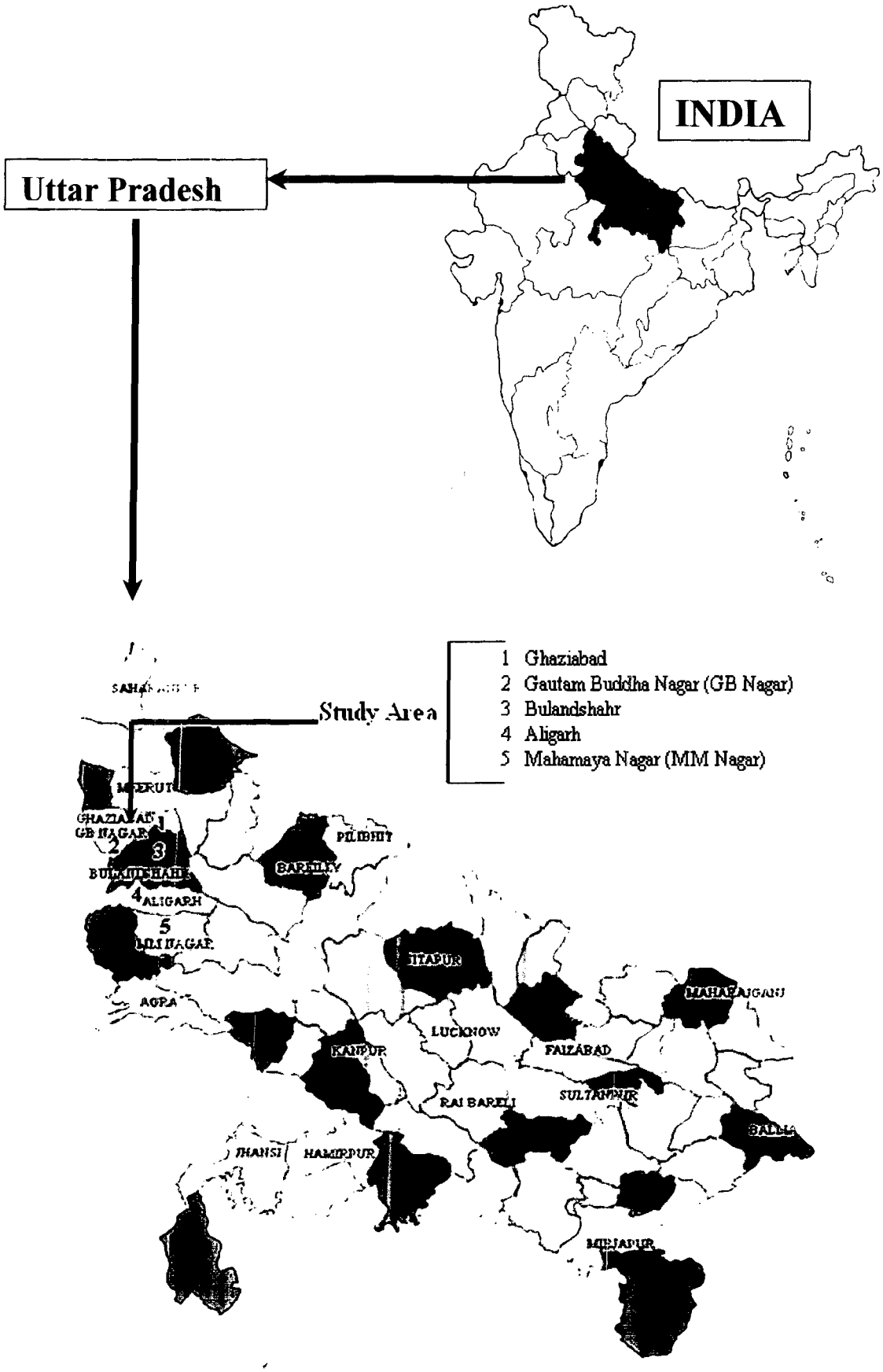


Fig.1: Position of study area in Uttar Pradesh, India.

The incidence of disease in an area

$$= \frac{\text{No. of infected samples in an area}}{\text{Total no. of collected samples from the same area}} \times 100$$

The incidence of disease on a crop

$$= \frac{\text{No. of infected samples of a crop}}{\text{Total no. of collected samples of the same crop}} \times 100$$

Frequency of occurrence of a species in an area

$$= \frac{\text{No. of infected samples with a species in an area}}{\text{Total no. of infected samples from the same area}} \times 100$$

Frequency of occurrence of a species on a crop

$$= \frac{\text{No. of infected samples with a species on a crop}}{\text{Total no. of infected samples from the same area}} \times 100$$

The disease intensity in terms of gall index (GI) and egg mass index (EMI) were calculated on 0-5 scale of Taylor and Sasser (1978):

0 = 0, 1 = 1 – 2, 2 = 3 – 10, 3 = 11 – 30, 4 = 31 – 100 and 5 = more than 100.

Maintenance of Species in Pure Culture

Frequently occurred two species, *M. incognita* and *M. javanica* were multiplied in pure form from single egg mass culture separately for further studies. The cultures were maintained on susceptible cultivar of

tomato Pusa Ruby in winter and on eggplant cultivar Pusa Kranti in summer.

Preparation of Inoculum

For preparing inoculum in form of 2nd stage juveniles (J2), egg masses of *M. incognita* and *M. javanica* populations maintained on tomato/eggplant in greenhouse were collected from the roots and incubated in sterilized water in an incubator at 25°C for 72 hours. The freshly hatched juveniles were collected as water suspension and their number/ml were standardized by counting into ten 1 ml sample from the suspension.

Source of Fly Ash

A Thermal Power Plant is situated in Kasimpur 20 km away from the Department of Botany, AMU, Aligarh, India. This power plant releases huge amount of fly ash daily in a fly ash-pond (Fig. 2). Fresh fly ash was collected in gunny bags from 5 different points of fly ash-pond and brought to laboratory.

Collection of Soil

For experimental work, soil was collected from agricultural fields upto a depth of 20 cm, after scrapping of the surface litters. Before utilization the soil was autoclaved.

Fig.2: Releasing of fly ash through pipe from Thermal Power Plant, Kasimpur, into fly ash pond.

Autoclaving

Normal field soil kept in gunny bags was steam sterilized in the autoclave at 20 lb pressure for 20 minutes. The autoclaved soil was dried and then mixed with fly ash in different ratios separately.

Test Plants

Three important Indian vegetables-okra (*Abelmoschus esculentus* (L.) Moen.) cv. Long Green, cucumber (*Cucumis sativus* L.) cv. Poona Kheera and Pepper (*Capsicum annuum* L.) cv. Suryamukhi Green were selected as test plants. The certified seeds were used for the experiments.

Experiment 2

Analysis of Fly Ash and Amended Soil

Physico-chemical properties of fly ash, soil and fly ash amended soils before planting were analyzed to observe their compositions.

a) *Soil pH*

Twenty g soil sample was taken in a 100 ml beaker and 40 ml of double distilled water (DDW) was added into it. The suspension (1:2) was stirred at regular intervals for 30 minutes and the pH was recorded by pH meter.

b) *Electrical Conductivity (mmhos cm^{-1})*

Fifty g soil sample was taken in a 250 ml conical flask, containing 100 ml DDW. After shaking for half an hour, flask was left overnight. The soil suspension was filtered through the Whatman filter paper No-1.

Conductance was directly recorded by dipping the conductivity cell of a conductivity meter into the solution. Temperature was maintained and correlated with the table.

c) *Cation Exchange Capacity (mEq/100g)*

Cation exchange capacity (CEC) was measured by the method of Jackson (1973). Ten g soil sample was treated with sufficient amount of 0.1 N HCl. After half an hour, soil solution was washed with DDW through filter paper till the removal of all acidity. The acidity was determined by pH meter. Then soil was kept in saturated solution of KCl for 15 min. After half an hour, again it was filtered and filtrate was treated with standardized 0.1 N NaOH solution till the colour changed. Cation exchange capacity was calculated by the following formula.

$$CEC = \frac{V}{10} \times 100 \text{ mEq/100g soil}$$

V= Volume of 0.1 N NaOH used

d) *Water Holding Capacity (%)*

For measuring the water holding capacity, air-dried soil sample was crushed in a porcelain mortar. After complete crushing, particles were passed through a small sieve of 1.5 mm holes and course particles were removed from the sieve. The weight of the circular brass box with perforated bottom having filter paper on bottom was taken (W_1). Then, it was filled with soil and kept in hot air oven (105°C) for complete drying of soil. After drying, the weight was taken again (W_2). Now box was

submerged in a petri-dish containing water up to 1/4th level and left for 12 hrs. After that the box was gently taken out from the petri-dish and excess water was allowed to evaporate at room temperature (27°C) and was weighed finally (W_3).

Calculation:

$$\text{Water holding capacity} = \frac{W_3 - W_2}{W_2 - W_1} \times 100$$

e) *Sulphate Content (mg/l)*

For estimation of sulphate content, method of Jackson (1973) was applied. Three reagents; conditioning reagents, barium chloride and standard sulphate solution were used.

In 100 ml soil solution (soil: water = 1:5), 50 ml conditioning reagent was added. After stirring the solution, $BaCl_2$ crystals were added and stirred again for one minute. The readings were taken on a spectrophotometer at 420 nm and the concentration of sulphate was determined from the standard curve, within a range of 0.0-40 mg/l with the difference of 5 mg/l.

f) *Chloride Content (mg/l)*

The chloride content was estimated by the method of Jackson (1973). Three reagent; 0.02 N sodium chloride, 0.02 N silver nitrate and potassium chromate indicator were prepared separately.

The 5 ml soil filtrate was placed in a porcelain dish and diluted with 25 ml DDW. After adding 5-6 drops of K_2CrO_4 indicator, it was titrated

against standard $AgNO_3$ solution till the brick red tinge appeared. Calculation was done as follows.

1 ml of 0.02 N $AgNO_3$ = 0.00071 g of chloride

Chloride = V × 4 mEq/l

V= Volume of 0.02 N $AgNO_3$ used in titration

mg/l = mEq/ l × equivalent weight

(equivalent weight of Cl^- = 35.5)

g) ***Available Nitrogen (mg/Kg)***

For extracting the nitrogen in soil samples, alkaline permanganate method was employed (Gupta, 2004). Six reagents potassium permanganate solution of 0.32%, sodium hydroxide of 2.5%, liquid paraffin (extra pure), 0.02 N sulphuric acid of 0.02 N and boric acid solution of 2% containing 20 ml of mixed indicator per litre were used.

About 20 g soil sample was taken in an 800 ml dry Kjeldahl flask and 20 ml each of 0.32% $KMnO_4$ and 2.5% NaOH solutions. The frothing during boiling was prevented by liquid paraffin (1 ml) and bumping by adding a few glass beads. The contents were distilled in Kjeldahl assembly at a steady rate and the liberated ammonia was collected in a conical flask containing 20 ml of boric acid solution (with mixed indicator). With the absorption of ammonia the pinkish colour turned to green. Nearly 100 ml of distillate was collected in 30 minutes which was titrated with 0.02 N H_2SO_4 till the original shade (pinkish)

come. Blank correction (without soil) was carried out for final calculation.

$$N\ (mg/Kg) = R \times 0.05 \times 0.014 \times 10^6$$

Where R = Volume of 0.02 N H_2SO_4 required for titration

h) ***Available Phosphorous (mg/Kg)***

The available phosphorous in soil samples was estimated by Olsen's method (Olsen *et al.*, 1954). The Olsen's reagent, Dickman and Bray's reagent, and stannous chloride solution were prepared.

Air dried soil sample 2.5 g was taken in 100 ml conical flask and a little quantity of Darco G60 was added followed by 50 ml of Olsen's reagent at 25°C. A blank was run without soil. The flasks were shaken for 30 minutes on a platform type shaker and the contents filtered immediately through dry filter paper (Whatman No. 1) into dry beaker.

Soil extract 5 ml was pipetted into a 25 ml volumetric flask. To this Dickman and Bray's reagent was added drop by drop with constant shaking till the effervescence due to CO_2 evolution ceased. The neck of the flask was washed down with DDW and the volume was made approximately 22 ml then one ml of the diluted stannous chloride solution was added and volume was made up to 25 ml. The intensity of the blue colour was measured at 660 nm using a spectrophotometer just after 10 minutes. The concentration of phosphorus was determined from the standard curve.

Calculation:

Available Phosphorus (μg) = R × (50/2.5) × (25/5)

= R × 100

R = μg phosphorus in the aliquot (Seen from the standard curve)

i) *Available Potassium (mg/kg)*

For estimation of available potassium two reagents ammonium acetate solution and standard KCl solution were prepared.

Now 5 g air dried soil was taken in a 50 ml centrifuge tube and 25 ml (1:5 soil to extractant) of neutral normal ammonium acetate was added, tube was stoppered and shaked for 10 minutes. This solution was centrifuged at 2000 rpm for 10 minutes until the supernatant liquid became clear. The supernatant liquid was decanted into a 100 ml volumetric flask. Three additional extractions were made in the same manner. Diluted the combined extracts to 100 ml with ammonium acetate and mixed. For determination of potassium in the extract, flame photometer was used.

A standard curve was plotted between concentrations and readings of standard K solution. Extract of the sample was taken and feeded in the flame photometer. Reading for each sample was noted and determined the K concentration in the sample with the help of standard curve.

SECTION-II

This was the major experimental section. It included the experiments of fly ash impact on hatching, mortality, penetration and development of root-knot nematodes on different vegetables.

Experiment 3

Hatching of Juveniles

For hatching experiment, fly ash-extract was prepared by adding two litres distilled water (D.W.) to one kg fly ash and left for overnight. After filtration following dilutions were prepared from the standard extract obtained.

H1= 100 ml distilled water (D.W.) (0% conc.) Control

H2= 5 ml fly ash-extract + 95 ml D.W. (5% conc.)

H3= 10 ml fly ash-extract + 90 ml D.W. (10% conc.)

H4= 20 ml fly ash-extract + 80 ml D.W. (20% conc.)

H5= 30 ml fly ash-extract + 70 ml D.W. (30% conc.)

H6= 40 ml fly ash-extract + 60 ml D.W. (40% conc.)

H7= 50 ml fly ash-extract + 50 ml D.W. (50% conc.)

H8= 75 ml fly ash-extract + 25 ml D.W. (75% conc.)

H9= 100 ml fly ash-extract only (100% conc.)

Ten ml of these different dilutions were poured into 5 cm diameter petri dishes separately. Five average sized egg masses of *M. incognita* or

M. javanica obtained from pure population were placed in each petri dish. Each treatment was replicated 5 times. A set of 5 petri dishes receiving distilled water served as control. Total 360 petri dishes were used (9 treatments x 4 intervals x 5 replicates x 2 nematodes). Petri dishes were kept at room temperature (25-27°C). After 1st, 3rd, 5th and 7th day hatched juveniles were counted under stereoscopic microscope. Mean was taken and per cent inhibition over control was determined. Data were analyzed statistically for significance.

Experiment 4

Mortality of Juveniles

For mortality experiment, the same dilutions of fly ash-extract for 9 treatments were prepared as in case of hatching experiment 3.

Five ml nematode suspension containing about 100 juveniles of *M. incognita* or *M. javanica* were poured into a small sieve of 350 mesh sized. Immediately 10ml dilutions was pipetted from back of sieve in such a way that juveniles + solution were transferred to a 5cm diameter petri dish. This process was done for each treatment. Each treatment was replicated five times. A set of five petri dishes containing 5 ml D.W. and 5 ml nematode suspension served as control. Total 360 petri dishes were used (9 treatments x 4 intervals x 5 replicates x 2 nematodes). After different intervals (1st, 3rd, 5th and 7th day) the dead larvae were counted under stereoscopic microscope and mortality percentages were calculated. Data were analyzed statistically for significance.

Experiments 5 to 10

Penetration of Juveniles

For penetration experiment different ratios of fly ash were mixed with autoclaved soil to obtain following levels (w/w).

P1= Control (only autoclaved soil) (0% level)

P2= 5% fly ash + 95% autoclaved soil (5% level)

P3= 10% fly ash + 90% autoclaved soil (10% level)

P4= 20% fly ash + 80% autoclaved soil (20% level)

P5= 30% fly ash + 70% autoclaved soil (30% level)

P6= 40% fly ash + 60% autoclaved soil (40% level)

P7= 50% fly ash + 50% autoclaved soil (50% level)

P8= 75% fly ash + 25% autoclaved soil (75% level)

P9= 100% fly ash only fly ash (100% level)

Disposable cups of 7 cm size were filled with different fly ash mixtures separately. Total 180 cups (9 treatments x 4 intervals x 5 replicates) were used for each crop for each nematode. Seeds of okra and cucumber were directly sown to respective cups but for pepper, fifteen days old seedlings at 4-leaves-stage were transplanted to each cup. After 10 days, seedlings were inoculated with 500 freshly hatched juveniles of *M. incognita* or *M. javanica*. Cups were placed on glass house bench at 25-27° C. Penetrated juveniles were observed after 1st, 3rd, 5th and 7th day.

For this purpose, 5 seedlings from each treatment were harvested carefully from the cups and roots were cut and gently boiled in acid fuchsin (0.1%) + lactophenol solution. Each root was observed separately under stereoscopic microscope for the presence of juveniles. Then per cent penetration was calculated for each treatment. Data were analyzed statistically for significance.

Experiments 11 to 16

Development of Juveniles

For this experiment the fly ash and soil were mixed as mentioned in penetration experiments. One kg mixture was filled in 15 cm clay pots. The pots containing only soil served as control. Total 180 pots (9 treatments x 4 weeks x 5 replicates) were prepared for each crop for each nematode. Seeds of okra and cucumber were directly sown in pots, however fifteen-days-old pepper seedlings were transplanted to each type of mixture. After 10 days, seedlings were inoculated with 1000 juveniles of *M. incognita* or *M. javanica*, obtained from the pure population. Five plants were harvested from each treatment at different intervals (1^{st}, 2^{nd}, 3^{rd} and 4^{th} week). Roots were thoroughly washed with gentle stream of water to avoid soil particles and debris. Each root was slightly boiled in acid fuchsin (0.1%) + lactophenol solution separately. Different stages of larvae were counted under stereoscopic microscope. The data were analyzed statistically for significance.

SECTION-III

This section included the experiments of fly ash impact on vegetables with and without root-knot nematodes.

Experiments 17, 20 and 23

Impact of Fly Ash on Plant

For growth performance, same treatments of previous experiments (Development of Juveniles) with five replicates were taken. However, in these experiments, nematode was not added. Thus there were only 135 pots (9 treatments x 5 replicates x 3 crops). Pots were arranged in randomized block design on glass house benches. After two months, plants were harvested carefully.

a) ***Plant Growth and Yield***

The plant growth (length, fresh wt. and dry wt. of root and shoot; leaf area; leaf/ plant) and yield (flower/plant; fruit/plant) were taken after termination of experiments.

Shoot length was taken from the point of emergence of the root to the shoot apex. While root length was recorded from root emergence to longest root and both were recorded in centimeter (cm). Fresh weight of roots and shoots were recorded in gram (g). After taking fresh weight, roots and shoots were dried in a hot air oven at 80°C for 48 hrs and their dry weights were recorded.

Leaf area was estimated by graph paper and the number of squares of 1 cm^2 enclosed within it was counted. Leaves were counted in number per plant. Flowers and fruits were counted in number per plant as yield parameters. Data were analyzed statistically.

a) *Photosynthetic Pigments*

Photosynthetic pigments were estimated by Mac Lachlan and Zalik (1963) method. After 60 days of planting, one g fresh leaves were ground in 80 % acetone with the help of mortar and pestle. The suspension was filtered through the Whatman filter paper No. 1 to the 100 ml volumetric flask and made to the known volume by adding 80% acetone. Optical density (O.D.) was read at 645 nm and 663 nm for chlorophyll a and b and at 480 nm and 510 nm for carotenoids against 80% acetone as blank on spectrophotometer. The concentration of chlorophyll a, chlorophyll b and total chlorophyll and carotenoids present in the given extract were calculated according to the formulae given below.

$$\text{a)}\quad \text{Chl. a} = \frac{12.7\,(\text{O.D. } 663) - 2.69\,(\text{O.D. } 645)}{1000 \times \text{W}} \times \text{V mg/g}$$

$$\text{b)}\quad \text{Chl. b} = \frac{22.9\,(\text{O.D. } 645) - 4.68\,(\text{O.D. } 663)}{1000 \times \text{W}} \times \text{V mg/g}$$

$$\text{c)}\quad \text{Total Chl.} = \frac{20.2\,(\text{O.D. } 645) + 8.02\,(\text{O.D. } 663)}{1000 \times \text{W}} \times \text{V mg/g}$$

d) Carotenoids = $\frac{7.6\ (O.D.\ 480) - 1.49\ (O.D.\ 510)}{D \times 1000 \times W}$ mg/g

O.D. = Optical density

D = Length of the light path

V = Total volume of the chlorophyll solution

W = Fresh weight of the leaf

Experiments 18, 19, 21, 22, 24 and 25

Impact of Fly Ash Application and Nematodes (5000 Juveniles) on Plants

For these experiments, same treatments of previous experiment 17 (Impact of Fly ash on Plant) were included. However, each pot was inoculated with 5000 juveniles of *M. incognita* or *M. javanica.* Total 270 pots were prepared (9 treatments x 5 replicates x 2 nematodes x 3 crops). After completion of experiment, plant growth, yield and photosynthetic pigments parameters were taken as mentioned in previous experiment.

After harvesting disease intensity in terms of gall index (GI) and egg mass index (EMI) were assigned as mentioned earlier. The reproduction factor (Rf) was calculated by formula: Rf = pf / pi (pf = Final population, pi = Initial population).

Experiments 26 to 31

Impact of Fly Ash (20%) with Different Inoculum Levels of Nematodes on Plants

For these experiments, 20% fly ash was used for each treatment. However, different inoculum levels of *M. incognita* or *M. javanica* (250, 500, 1000, 2500, 5000, 10,000 juveniles) were taken. The experiments were maintained and carried out exactly similar as mentioned in previous experiments. After harvest, same parameters of plant growth, yield and photosynthetic pigment were taken.

Statistical Analysis

Data were analyzed using analysis of variance for single factor (ANOVA) and L.S.D. values were calculated at P=0.05 and P=0.01 for significance (Gomez and Gomez, 1984).

RESULTS

The results of the thesis are divided into three main sections. Each section contains different experiments. The results of different experiments are given below.

SECTION-I

In this section survey, collection, identification, maintenance and raising of population of species of root-knot nematodes in pure form were done separately. Analysis of physico-chemical properties of different levels of fly ash amended soil was also determined.

Experiment 1

Survey, Collection and Identification of Root-Knot Nematode Species

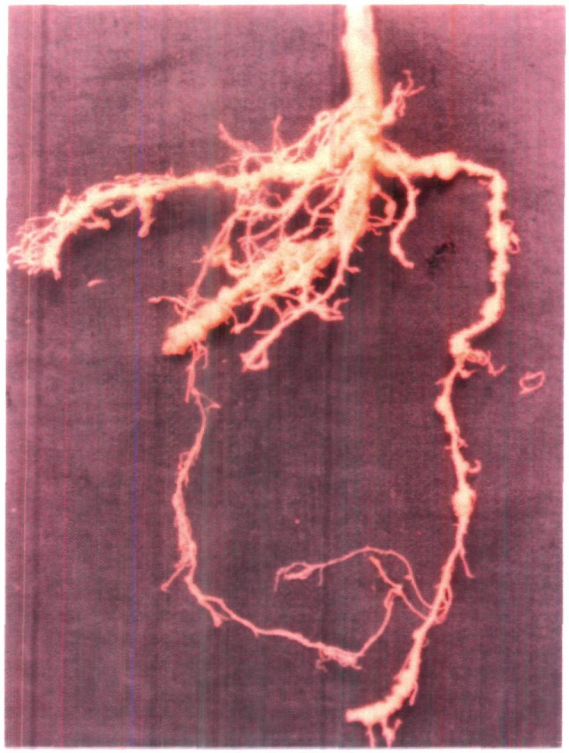
Surveys were conducted for root-knot nematodes in five districts of Western Uttar Pradesh (Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar). Infected root samples of eggplant, tomato, pepper, cucumber, okra and cabbage were collected (Figs. 3 and 4).

Occurrence of Root-Knot Nematodes in Aligarh District

Root samples of eggplant, tomato, pepper, cucumber, okra and cabbage were collected from different localities (Aligarh proper, Kasimpur, Atrauli, Khair and Barauli) of Aligarh district (Table 1). Out of 99 samples collected, 56 were infected. The highest incidence of root-knot disease was observed in Aligarh proper (72.22%) followed by Khair

Eggplant

Pepper



Cucumber

Okra

Fig.3: Root-knot disease on vegetables.

Tomato

Cabbage

Fig.4: Root-knot disease on vegetables.

Table 1: Incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in different localities of Aligarh district.

Locality/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
Localities									
Alig.Proper	18	13	72.22	46.15	30.77	23.08	1-4/1-3	1-3/1-2	1-4/0-3
Kasimpur	22	11	50.00	45.45	36.36	18.18	1-3/1-2	1-4/1-3	1-3/0-2
Atrauli	19	11	57.89	36.36	54.55	0.09	2-5/1-4	1-5/1-4	1-3/1-2
Khair	21	13	61.90	46.15	53.85	-	1-4/1-4	1-5/1-3	-
Barauli	19	08	42.11	62.50	37.50	-	1-5/1-5	1-4/0-3	-
Total	**99**	**56**	**56.57**	**46.43**	**42.86**	**10.71**	**1-5/1-5**	**1-5/0-4**	**1-4/0-3**
Vegetables									
Eggplant	29	22	75.86	50.00	36.36	13.64	1-5/1-5	1-5/1-3	1-3/0-2
Tomato	27	17	62.96	35.29	52.94	11.76	1-5/1-4	1-5/1-4	1-3/0-2
Pepper	16	07	43.75	57.14	28.57	14.29	2-5/1-4	1-4/0-4	1-4/0-3
Cucumber	07	00	-	-	-	-	-	-	-
Okra	12	07	58.33	42.86	57.14	-	1-4/1-3	1-5/1-4	-
Cabbage	08	03	37.50	66.67	33.33	-	2-4/1-4	1-5/1-4	-
Total	**99**	**56**	**56.57**	**46.43**	**42.86**	**10.71**	**1-5/1-5**	**1-5/0-4**	**1-4/0-3**

Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.

(61.90%), Atrauli (57.89%), Kasimpur (50.00%) and Barauli (42.11%). Overall frequency of disease in the district was 56.57%. Three species of root-knot nematodes viz. *M. incognita*, *M. javanica* and *M. arenaria* were identified. *M. incognita* and *M. javanica* were present in all the five localities of the district, while *M. arenaria* was present in Aligarh proper, Kasimpur and Atrauli. Frequency of occurrence of *M. incognita* was highest (46.43%) in the district followed by *M. javanica* (42.86%) and *M. arenaria* (10.71%).

Among vegetables the highest frequency of root–knot disease was noticed on eggplant (75.86%) followed by tomato (62.96%), okra (58.33%), pepper (43.75%) and cabbage (37.50%). Cucumber was free from disease. *M. incognita* and *M. javanica* were present on all vegetables except cucumber. While *M. arenaria* was present on eggplant, tomato and pepper only. Intensity of the disease on the basis of GI/EMI showed a wide range of variation (1-5/0-5). The highest intensity of disease was observed by *M. incognita* (1-5/1-5) followed by *M. javanica* (1-5/0-4) and *M. arenaria* (1-4/0-3).

Occurrence of Root-Knot Nematodes in Bulandshahr District

Table 2 indicates that total 88 root samples of vegetables (eggplant, tomato, pepper, cucumber and cabbage) were collected from different localities (Bulandshahr proper, Narayanpur, Khurja, Siyana, Dibai) of Bulandshahr district. Out of 88 samples, 46 were infected. The highest incidence of root-knot disease was observed in Narayanpur (64.71%)

Table 2: Incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in different localities of Bulandshahr district.

Locality/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
Localities									
Buland.Proper	24	11	45.83	54.55	36.36	9.09	2-5/2-3	1-4/0-4	1-4/1-2
Narayanpur	17	11	64.71	45.45	45.45	9.09	1-5/1-4	2-4/2-4	1-3/1-2
Khurja	14	06	42.86	66.67	33.33	-	3-5/2-3	1-4/1-4	-
Siyana	11	06	54.55	50.00	33.33	16.67	1-4/1-3	1-4/1-3	1-3/0-2
Dibai	22	12	54.55	50.00	41.67	8.33	1-4/1-2	1-4/0-4	2-4/1-2
Total	**88**	**46**	**52.27**	**52.17**	**39.13**	**8.70**	**1-5/1-4**	**1-4/0-4**	**1-4/0-2**
Vegetables									
Eggplant	25	18	72.00	55.56	33.33	11.11	2-4/1-3	1-4/0-3	1-3/0-2
Tomato	22	14	63.64	35.71	57.14	7.14	1-4/1-2	1-4/0-4	1-4/0-2
Pepper	14	06	42.86	50.00	33.33	16.67	3-5/1-3	2-4/1-4	1-2/0-2
Cucumber	13	05	38.46	60.00	40.00	-	1-5/1-3	1-4/1-3	-
Cabbage	14	03	21.43	100.00	-	-	1-5/1-4	-	-
Total	**88**	**46**	**52.27**	**52.17**	**39.13**	**8.70**	**1-5/1-4**	**1-4/0-4**	**1-4/0-2**

Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.

followed by Siyana and Dibai (54.55%), Bulandshahr proper (45.83%) and Khurja (42.86%). Overall frequency of disease in the district was 52.27%. Three species of root-knot nematodes viz. *M. incognita*, *M. javanica* and *M. arenaria* were identified. All three species were present in all localities except *M. arenaria* which was not found in Khurja. Frequency of occurrence of *M. incognita* was highest (52.17%) in the district followed by *M. javanica* (39.13%) and *M. arenaria* (8.70%).

Highest frequency of occurrence of root–knot was noticed on eggplant (72.00%) followed by tomato (63.64%), pepper (42.86%), cucumber (38.46%) and cabbage (21.43%). *M. incognita* was present on all vegetables. *M. javanica* was absent on cabbage, while *M. arenaria* was absent on cucumber and cabbage. Overall intensity of the disease in terms of GI and EMI was 1-5 and 0-4 respectively. The highest intensity of disease was observed by *M. incognita* (1-5/1-4) followed by *M. javanica* (1-4/0-4) and least by *M. arenaria* (1-4/0-2).

Occurrence of Root-Knot Nematodes in Gautam Buddha Nagar District

Total 71 root samples of vegetables (eggplant, tomato, pepper, cucumber, okra and cabbage) were collected from different localities (G B Nagar, Dadri, Dankaur and Jahangirpur) in Gautam Buddha Nagar district (Table 3). The 34 samples were infected with root-knot nematodes. The highest incidence of disease was found in G B Nagar and Dadri (50.00%) followed by Dankaur (47.62%) and Jahangirpur

Table 3: Incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in different localities of Gautam Buddha Nagar district.

Locality/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
Localities									
G.B. Nagar	14	07	50.00	42.86	42.86	14.29	2-4/1-4	2-5/1-4	1-3/0-2
Dadri	18	09	50.00	33.33	44.44	22.22	2-4/0-4	3-4/2-4	1-2/0-1
Dankaur	21	10	47.62	30.00	60.00	10.00	1-4/1-3	1-4/1-3	1-3/1-2
Jahangirpur	18	08	44.44	50.00	37.50	12.50	1-4/0-4	1-5/1-4	1-3/0-2
Total	**71**	**34**	**47.89**	**38.24**	**47.06**	**14.71**	**1-4/0-4**	**1-5/1-4**	**1-3/0-2**
Vegetables									
Eggplant	19	10	52.63	30.00	50.00	20.00	1-4/0-3	1-5/1-4	1-3/0-2
Tomato	14	09	64.29	33.33	44.44	22.22	1-3/0-3	1-4/1-3	1-3/1-2
Pepper	16	08	50.00	37.50	50.00	12.50	1-4/1-3	1-5/1-4	1-2/0-1
Cucumber	07	03	42.86	66.67	33.33	-	1-4/1-4	1-4/1-2	-
Okra	10	04	40.00	50.00	50.00	-	1-3/1-2	1-5/1-3	-
Cabbage	05	00	-	-	-	-	-	-	-
Total	**71**	**34**	**47.89**	**38.24**	**47.06**	**14.71**	**1-4/0-4**	**1-5/1-4**	**1-3/0-2**

Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.

(44.44%). Overall frequency of disease in the district was 47.89%. Three species of root-knot nematodes viz. *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in all the localities of the district. Frequency of occurrence of *M. javanica* was highest (47.06%) in the district followed by *M. incognita* (38.24%) and *M. arenaria* (14.71%).

Among vegetables, the highest frequency of disease was noticed on tomato (64.29%) followed by eggplant (52.63%), pepper (50.00%), cucumber (42.86%) and okra (40.00 %). Cabbage was free from disease. *M. incognita* and *M. javanica* were present on all vegetables except cabbage. While *M. arenaria* was present on eggplant, tomato and pepper only. Intensity of the disease on the basis of GI/EMI was 1-5/0-4. The highest intensity was observed by *M. javanica* (1-5/1-4) followed by *M. incognita* (1-4/0-4) and then *M. arenaria* (1-3/0-2).

Occurrence of Root-Knot Nematodes in Ghaziabad District

Total 67 root samples of eggplant, tomato, pepper and cucumber were collected from different localities (Ghaziabad proper, Pilakhuwa, Hapur and Muradnagar) in Ghaziabad district (Table 4). Out of 67 collected samples, 34 were infected. The highest incidence of root-knot disease was observed in Pilakhuwa (61.54%) followed by Ghaziabad proper and Hapur (50.00%) and then Muradnagar (44.44%). Overall frequency of disease in the district was 50.75%. *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in all four localities of Ghaziabad district except *M. arenaria* which was absent in

Table 4: Incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in different localities of Ghaziabad district.

Locality/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
Localities									
Ghaz.Proper	20	10	50.00	50.00	30.00	20.00	1-5/1-4	1-4/0-4	1-4/1-3
Pilakhuwa	13	08	61.54	50.00	37.50	12.50	1-4/1-3	1-4/0-3	1-2/0-2
Hapur	16	08	50.00	62.50	37.50	-	1-5/0-5	1-3/0-3	-
Muradnagar	18	08	44.44	37.50	50.00	12.50	1-4/1-3	1-4/0-4	1-3/0-3
Total	**67**	**34**	**50.75**	**50.00**	**38.24**	**11.76**	**1-5/0-5**	**1-4/0-4**	**1-4/0-3**
Vegetables									
Eggplant	22	14	63.64	35.71	50.00	14.29	1-4/0-4	1-4/1-3	1-3/0-3
Tomato	18	09	50.00	55.56	33.33	11.11	1-4/1-3	1-3/0-3	1-3/1-2
Pepper	15	07	46.67	57.14	28.57	14.29	1-5/1-4	1-4/0-4	1-4/1-3
Cucumber	12	04	33.33	75.00	25.00	-	1-5/1-5	1-3/1-2	-
Total	**67**	**34**	**50.75**	**50.00**	**38.24**	**11.76**	**1-5/0-5**	**1-4/0-4**	**1-4/0-3**

Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.

Hapur. Frequency of occurrence of *M. incognita* was highest (50.00%) in the district followed by *M. javanica* (38.24%) and *M. arenaria* (11.76%).

Highest frequency of root–knot disease was observed on eggplant (63.64%) followed by tomato (50.00%), pepper (46.67%) and cucumber (33.33%). *M. incognita* and *M. javanica* were present on all the four vegetables. While *M. arenaria* was absent on cucumber. Intensity of the disease on the basis of GI/EMI showed a wide range of variation (1-5/0-5). The highest intensity was observed by *M. incognita* (1-5/0-5) followed by *M. javanica* (1-4/0-4) and *M. arenaria* (1-4/0-3) (Table 4).

Occurrence of Root-Knot Nematodes in Mahamaya Nagar District

Table 5 shows that total 73 root samples of eggplant, tomato, pepper, cucumber, okra and cabbage were collected from different localities (Hathras, Sikandrarau, Sasni and Iglas) of Mahamaya Nagar district. Of the collected samples, 35 were infected. The highest incidence of root-knot disease was observed in Hathras (56.25%) followed by Iglas (50.00%), Sikandrarau (44.44%) and Sasni (42.11%). Overall frequency of disease in the district was 47.95%. Three species of root-knot nematodes viz. *M. incognita*, *M. javanica* and *M. arenaria* were identified in all the four localities. Frequency of occurrence of *M. incognita* was highest (48.57%) in the district followed by *M. javanica* (37.14%) and *M. arenaria* (14.29%).

On vegetables the highest frequency of occurrence of root–knot disease was found on eggplant (65.00%) followed by tomato (62.50%),

Table 5: Incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in different localities of Mahamaya Nagar district.

Locality/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
Localities									
Hathras	16	09	56.25	55.56	33.33	11.11	1-5/1-4	1-4/1-3	1-3/0-3
Sikandrarau	18	08	44.44	50.00	37.50	12.50	1-5/0-4	1-4/1-3	1-4/1-3
Sasni	19	08	42.11	25.00	50.00	25.00	1-4/1-3	1-5/0-4	1-3/1-2
Iglas	20	10	50.00	60.00	30.00	10.00	1-4/0-4	1-4/0-3	1-3/0-2
Total	**73**	**35**	**47.95**	**48.57**	**37.14**	**14.29**	**1-5/0-4**	**1-5/0-4**	**1-4/0-3**
Vegetables									
Eggplant	20	13	65.00	46.15	30.77	23.08	1-5/1-4	1-4/1-3	1-4/0-3
Tomato	16	10	62.50	40.00	50.00	10.00	1-4/0-4	1-5/1-4	1-3/1-2
Pepper	12	05	41.67	60.00	40.00	-	1-5/1-4	1-4/1-3	-
Cucumber	09	03	33.33	66.67	33.33	-	1-5/1-4	1-5/1-3	-
Okra	10	04	40.00	50.00	25.00	25.00	1-4/1-3	1-4/0-4	1-4/1-3
Cabbage	06	00	-	-	-	-	-	-	-
Total	**73**	**35**	**47.95**	**48.57**	**37.14**	**14.29**	**1-5/0-4**	**1-5/0-4**	**1-4/0-3**

Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.

pepper (41.67%), okra (40.00%) and cucumber (33.33%). Cabbage was free from disease. *M. incognita* and *M. javanica* were present on all vegetables except cabbage. While *M. arenaria* was present on eggplant, tomato and okra only. Intensity of the disease in terms of GI/EMI was 1-5/0-4. The intensity caused by *M. incognita* and *M. javanica* were highest (1-5/0-4) while intensity caused by *M. arenaria* was least (1-4/0-3).

Overall Occurrence of Root-Knot Nematodes in Western Uttar Pradesh

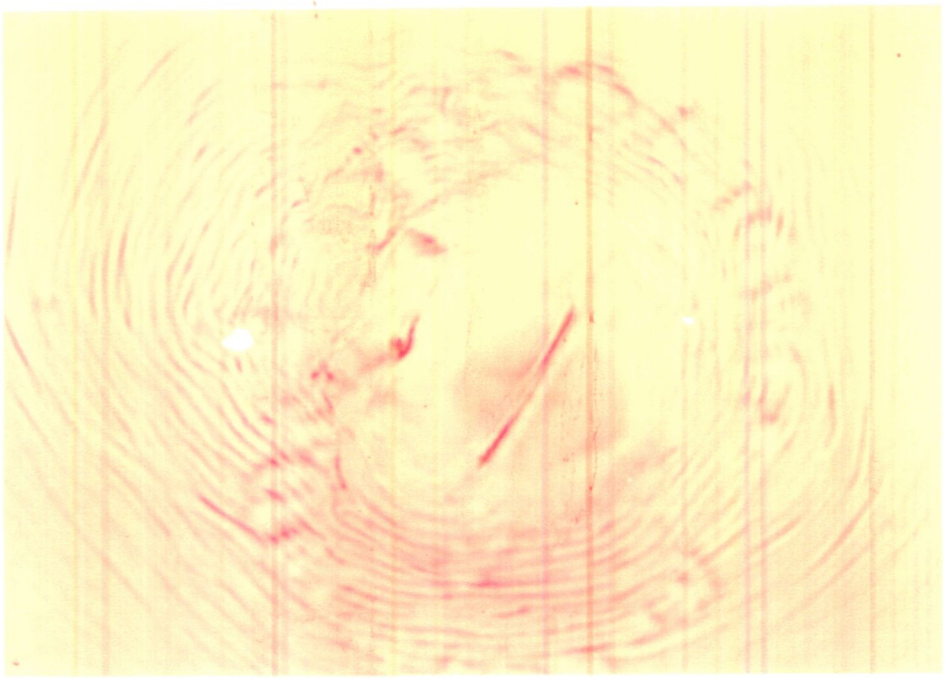
Total 398 root samples of vegetables (eggplant, tomato, pepper, cucumber, okra and cabbage) were collected from five districts (Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar) in the area (Table 6). Out of 398 collected samples, 205 were infected with root-knot nematodes. The highest incidence of root-knot disease was observed in Aligarh district (56.57%) followed by Bulandshahr (52.27%), Ghaziabad (50.75%), Mahamaya Nagar (47.95%) and Gautam Buddha Nagar (47.89%). Overall frequency of disease in the area was 51.51%. Three species of root-knot nematodes viz. *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in the area (Fig. 5). Frequency of occurrence of *M. incognita* was highest (47.32%) in the area followed by *M. javanica* (40.98%) and *M. arenaria* (11.71%).

On vegetables the highest frequency of occurrence of root–knot disease was observed on eggplant (66.96%) followed by tomato (60.82%), okra (46.88%), pepper (45.21%) and cucumber (31.25%). The

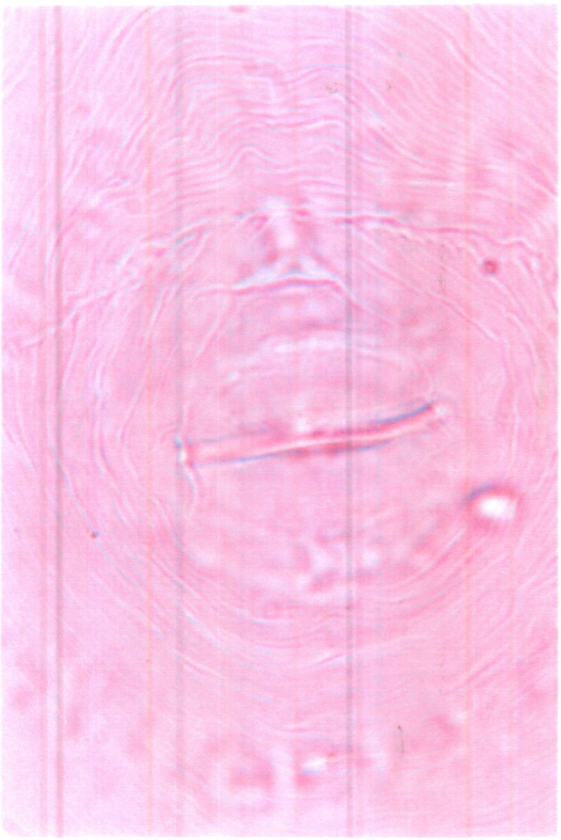
Table 6: Overall incidence, intensity, identity and frequency of occurrence of species of root-knot nematodes on vegetables in five districts of Western Uttar Pradesh.

District/ Vegetable	Incidence of disease			Frequency of species (%)			Intensity (GI/EMI)		
	Collected sample	Infected sample	Frequency (%)	Mi	Mj	Ma	Mi	Mj	Ma
District									
Aligarh	99	56	56.57	46.43	42.86	10.71	1-5/1-5	1-5/0-4	1-4/0-3
Bulandshahr	88	46	52.27	52.17	39.13	8.70	1-5/1-4	1-4/0-4	1-4/0-2
G. B. Nagar	71	34	47.89	38.24	47.06	14.71	1-4/0-4	1-5/1-4	1-3/0-2
Ghaziabad	67	34	50.75	50.00	38.24	11.76	1-5/0-5	1-4/0-4	1-4/0-3
MM. Nagar	73	35	47.95	48.57	37.14	14.29	1-5/0-4	1-5/0-4	1-4/0-3
Total	**398**	**205**	**51.51**	**47.32**	**40.98**	**11.71**	**1-5/0-5**	**1-5/0-4**	**1-4/0-3**
Vegetables									
Eggplant	115	77	66.96	45.45	38.96	15.58	1-5/0-5	1-5/0-4	1-4/0-3
Tomato	97	59	60.82	38.98	49.15	11.86	1-5/0-4	1-5/0-4	1-4/0-2
Pepper	73	33	45.21	51.52	36.36	12.12	1-5/1-4	1-5/0-4	1-4/0-3
Cucumber	48	15	31.25	66.67	33.33	-	1-5/1-4	1-5/1-3	-
Okra	32	15	46.88	46.67	46.67	6.67	1-4/1-3	1-5/1-4	1-4/1-3
Cabbage	33	06	18.18	83.33	16.67	-	1-5/1-4	1-5/1-4	-
Total	**398**	**205**	**51.51**	**47.32**	**40.98**	**11.71**	**1-5/0-5**	**1-5/0-4**	**1-4/0-3**

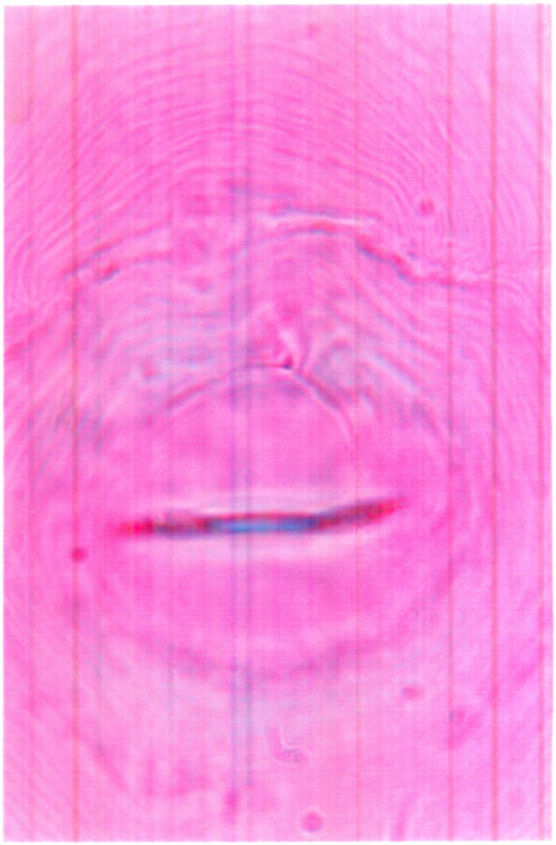
Mi= *Meloidogyne incognita*, Mj= *M. javanica*, Ma= *M. arenaria*; GI= Gall index, EMI= Egg mass index.



Meloidogyne incognita



Meloidogyne javanica



Meloidogyne arenaria

Fig.5: Perineal patterns of *Meloidogyne* species.

cabbage was least affected crop (18.18%). *M. incognita* and *M. javanica* were present on all vegetables. While *M. arenaria* was present on eggplant, tomato, pepper and okra only. Intensity of the disease on the basis of GI/EMI showed a wide range of variation (1-5/0-5). The highest intensity was observed by *M. incognita* (1-5/0-5) followed by *M. javanica* (1-5/0-4) and *M. arenaria* (1-4/0-3).

Experiment 2

Analysis of Physico-Chemical Properties of Fly Ash Amended Soil

Results given in table 7 show that physical properties as pH, electrical conductivity (EC), cation exchange capacity (CEC), water holding capacity (WHC) were increased gradually and significantly (P= 0.05 and P=0.01) as the levels of fly ash were increased when compared to control (soil), except pH and EC in level of 5% which were at par to control. Highest increase in these parameters was recorded at 100% fly ash level (Fig. 6).

Similarly the chemical properties of fly ash such as sulphate, chloride, phosphorus and potassium were gradually and significantly (P=0.05 and P=0.01) increased with respect to fly ash level in soil. However, as the level of fly ash was increased, the concentration of nitrogen was decreased (Table 7 and Fig. 7).

Table 7: Physico-chemical properties of soil, fly ash and amended soil.

Fly ash (%)	pH	EC (mmhos cm^{-1})	CEC (meq/100g)	WHC (%)	Sulphate (mg/l)	Chloride (mg/l)	Nitrogen (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)
C (Soil)	6.87	0.050	2.80	42.00	14.8	47.3	93	10.6	51.4
5	6.90	0.054	3.25	44.04	15.7	50.3	90	12.3	51.9
10	7.05	0.059	3.53	48.15	16.8	52.3	85	13.4	52.1
20	7.35	0.070	4.43	56.26	18.6	57.0	76	15.4	52.7
30	7.65	0.082	5.05	64.37	20.8	61.2	66	17.6	53.2
40	7.95	0.093	5.48	68.47	22.7	65.7	57	19.7	53.8
50	8.25	0.099	5.90	71.78	24.6	70.3	47	21.8	54.4
75	8.73	0.179	5.99	98.30	27.8	81.0	32	26.5	56.2
100 (FA)	9.18	0.192	6.88	112.5	32.5	90.5	12	30.6	57.0
LSD (P=0.05)	0.11	0.004	0.29	0.90	0.30	1.81	1.57	0.90	0.27
LSD (P=0.01)	0.15	0.005	0.40	1.21	0.41	2.45	2.14	1.20	0.36

C = Control, FA = Fly ash; EC = Electrical conductivity; CEC = Cation exchange capacity; WHC = Water holding capacity. Each value is a mean of five replicates.

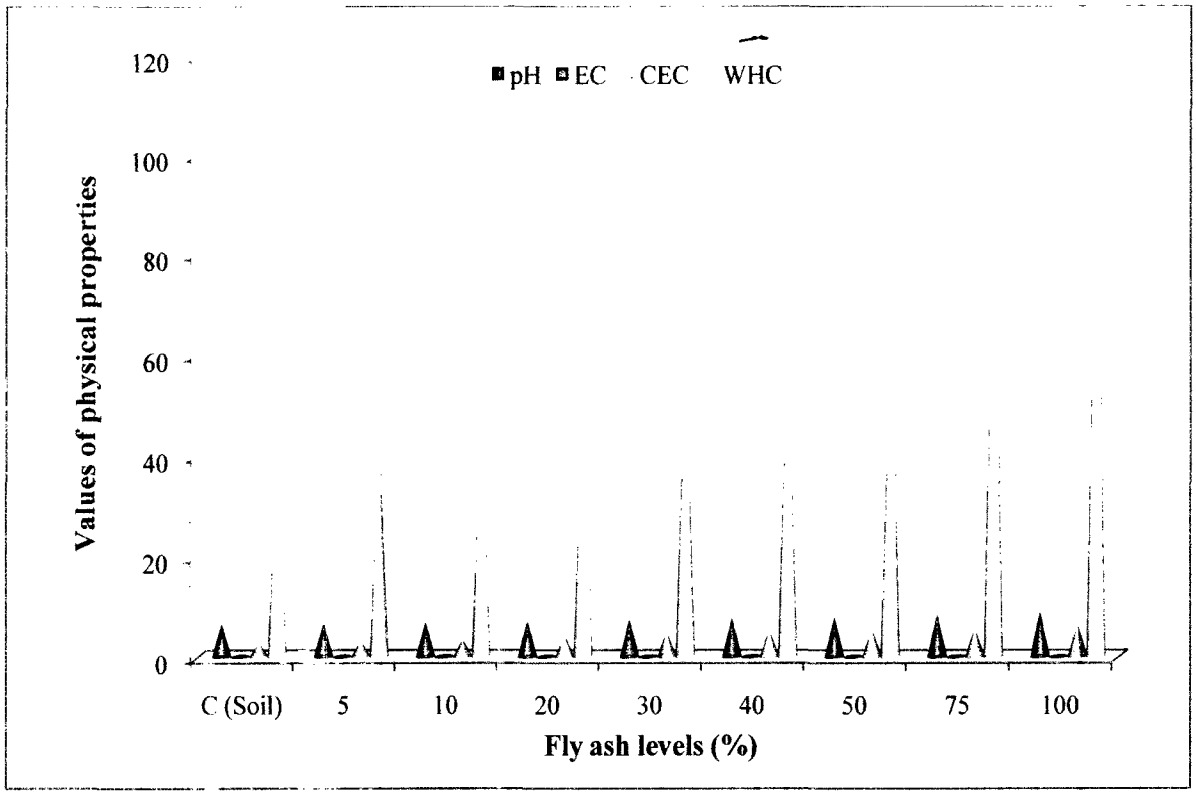


Fig.6: Physical properties of soil, fly ash and amended soil.

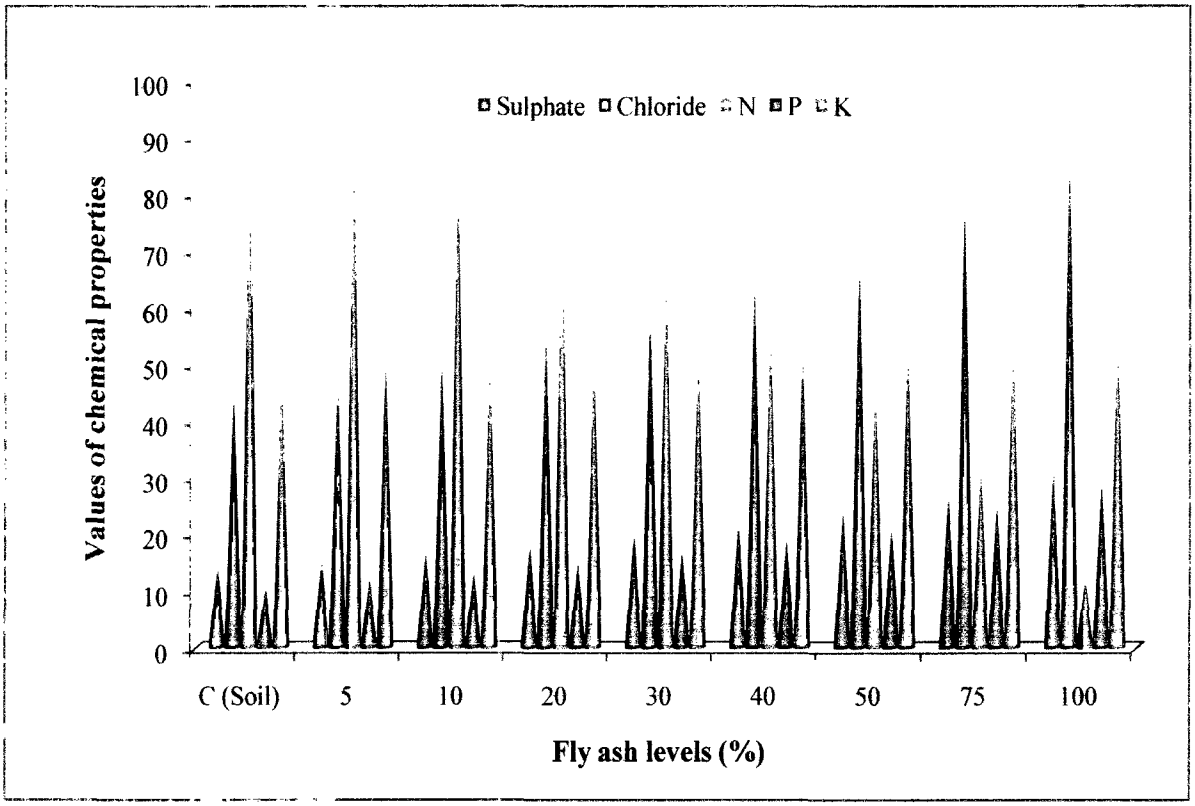


Fig.7: Chemical properties of soil, fly ash and amended soil.

SECTION-II

This section deals with the experiments of fly ash on hatching, mortality, penetration and development of *M. incognita* and *M. javanica* in okra, cucumber and pepper roots.

Experiment 3

Effect of Fly Ash-Extract on Hatching of *M. incognita* and *M. javanica* Juveniles

Different fly ash-extract levels were tested against hatching of juveniles of two frequently occurred species of root-knot nematodes, *M. incognita* and *M. javanica*. All the levels (5, 10, 20, 30, 40, 50, 75 and 100%) of fly ash-extract significantly (P=0.05 and P=0.01) impaired the hatching of *M. incognita* juveniles as compared to control at all time intervals (1^{st}, 3^{rd}, 5^{th} and 7^{th} day) (Table 8 and Fig. 8). Inhibition in hatching was directly proportional to the concentration of fly ash-extract. Hatching was completely checked at 100% fly ash level, in all days.

Similar results in hatching of *M. javanica* juveniles were also observed (Table 9). However, the effect of fly ash-extract levels was slightly greater on *M. javanica* as compared to *M. incognita*. As a result, hatching was slightly less in *M. javanica* than *M. incognita* (Fig. 8).

Experiment 4

Effect of Fly Ash-Extract on Mortality of *M. incognita* and *M. javanica* Juveniles

Table 8: Effect of different levels of fly ash-extract on hatching of *Meloidogyn incognita* juveniles.

Fly ash-extract (%)	Per cent inhibition over control after							
	1st day		3rd day		5th day		7th day	
	Hatching	Inhibition	Hatching	Inhibition	Hatching	Inhibition	Hatching	Inhibition
Control	325	-	497	-	637	-	806	-
5	235	27.69	354	28.77	448	29.67	565	29.90
10	208	36.00	316	36.42	400	37.21	500	37.97
20	185	43.08	281	43.46	346	45.68	424	47.39
30	137	57.85	205	58.75	257	59.65	305	62.16
40	94	71.08	135	72.84	151	76.30	175	78.29
50	52	84.00	69	86.12	79	87.60	87	89.21
75	13	96.00	17	96.58	20	96.86	24	97.02
100	00	100	00	100	00	100	00	100
LSD (P=0.05)	18.6		22.7		25.4		39.4	
LSD (P=0.01)	25.1		30.7		34.3		53.2	

Each value is a mean of five replicates.

Table 9: Effect of different levels of fly ash-extract on hatching of *Meloidogyne javanica* juveniles.

Fly ash-extract (%)	Per cent inhibition over control after							
	1st day		3rd day		5th day		7th day	
	Hatching	Inhibition	Hatching	Inhibition	Hatching	Inhibition	Hatching	Inhibition
Control	316	-	480	-	625	-	778	-
5	228	27.85	341	28.96	438	29.92	542	30.33
10	200	36.71	303	36.88	392	37.28	468	39.85
20	179	43.35	270	43.75	339	45.76	405	47.94
30	132	58.23	197	58.95	249	60.16	294	62.21
40	88	72.15	130	72.92	147	76.48	168	78.40
50	48	84.81	64	86.66	70	88.80	80	89.71
75	08	97.47	12	96.50	15	97.60	18	97.68
100	00	100	00	100	00	100	00	100
LSD (P=0.05)	18.5		21.7		25.1		33.2	
LSD (P=0.01)	25.4		29.4		33.3		45.8	

Each value is a mean of five replicates.

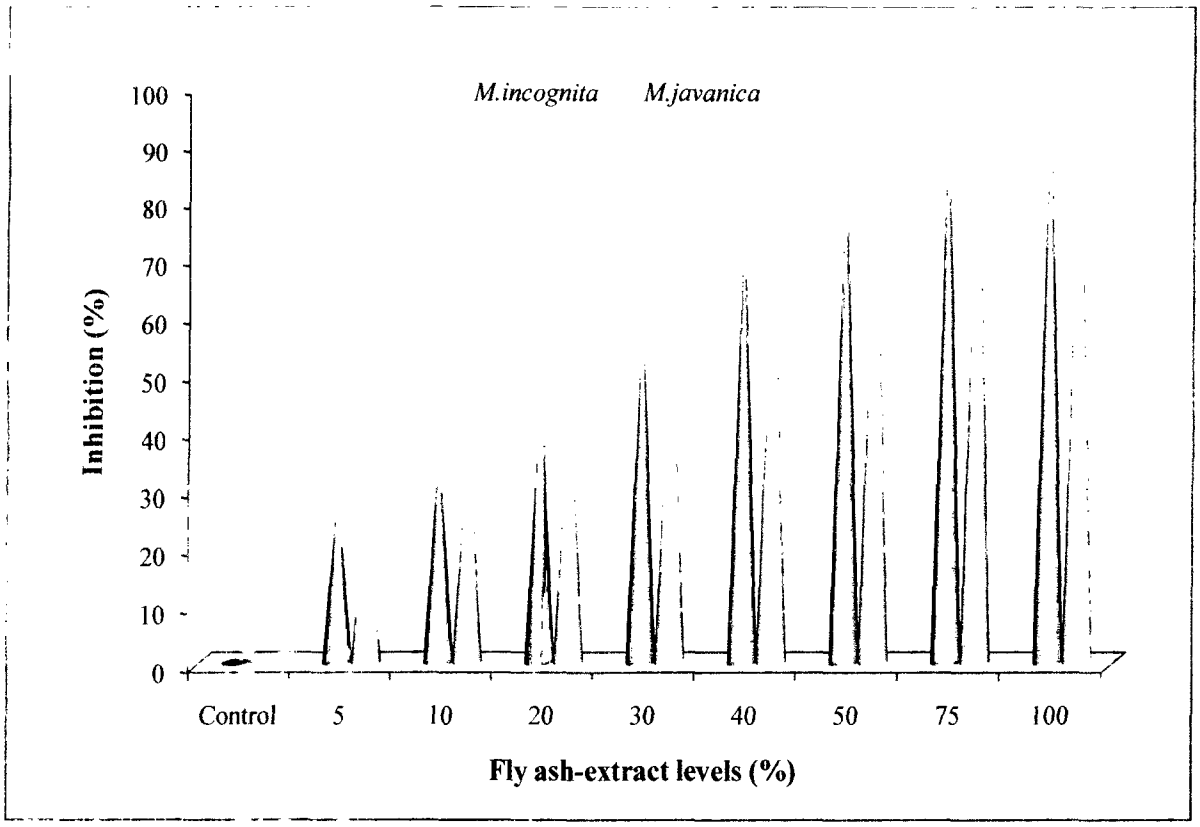


Fig.8: Effect of different fly ash-extract levels on hatching of juveniles after 7th day.

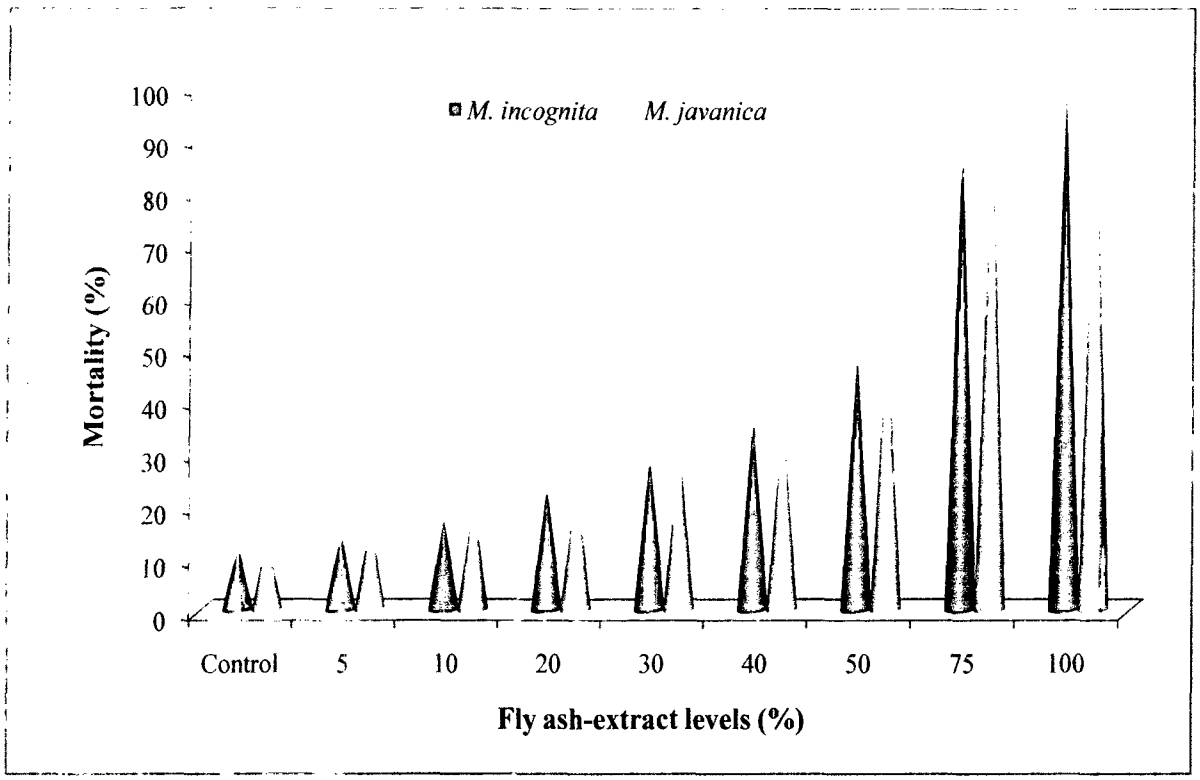


Fig.9: Effect of different fly ash-extract levels on mortality of juveniles after 7th day.

The mortality percent of juveniles was observed with different levels (5, 10, 20, 30, 40, 50, 75 and 100%) of fly ash-extract in 1st, 3rd, 5th and 7th day. All the levels were harmful to *M. incognita* juveniles (Table 10). Killing of juveniles was started from 1st day to 7th day. As level was increased, the killing percentage of juveniles was also increased significantly (P=0.05 and P=0.01). Highest mortality (100%) was observed in 7th day with 100% fly ash-extract level and lowest (12.33%) with control (Fig. 9). Thus mortality was directly proportional to the level as well as number of days increased.

Similar results were also observed with *M. javanica* juveniles (Table 11). However, juveniles of *M. javanica* were killed slightly more in number as compared to *M. incognita* (Fig. 9).

Experiments 5 and 6

Effect of Fly Ash on Penetration of *M. incognita* and *M. javanica* Juveniles in Okra Roots

The data given in table 12 shows that all the levels of fly ash in soil (5, 10, 20, 30, 40, 50, 75, and 100%) were harmful to both the nematodes. The penetration of *M. incognita* juveniles in okra roots was significantly (P=0.05 and P=0.01) suppressed at all time intervals (1st, 3rd, 5th and 7th day), except at 100% level, where penetration was completely checked in all days (Table 12). The lowest penetration was observed at 75% level (2.0%), while no penetration was observed at 100% level in 7th day

Table 10: Effect of different levels of fly ash-extract on mortality of *Meloidogyne incognita* (100 juveniles).

Fly ash-extract (%)	Per cent mortality of *Meloidogyne incognita*			
	1st day	3rd day	5th day	7th day
Control	5.00	7.00	9.67	12.33
5	6.33	8.33	11.00	15.00
10	7.67	10.00	14.33	17.33
20	9.67	11.67	18.00	23.67
30	11.67	14.00	23.00	29.67
40	13.67	17.33	28.00	36.67
50	17.33	21.33	36.00	49.33
75	46.67	52.00	65.67	90.00
100	80.00	100.00	100.00	100.00
LSD (P=0.05)	0.66	0.82	0.73	1.60
LSD (P=0.01)	0.92	1.16	1.04	2.16

Each value is a mean of five replicates.

Table 11: Effect of different levels of fly ash-extract on mortality of *Meloidogyne javanica* (100 juveniles).

Fly ash-extract (%)	Per cent mortality of *Meloidogyne javanica*			
	1st day	3rd day	5th day	7th day
Control	5.67	7.67	10.67	14.00
5	9.00	12.33	14.33	17.33
10	11.33	14.00	17.00	20.67
20	13.00	17.33	20.33	25.00
30	15.00	19.33	24.33	31.33
40	17.67	22.00	29.00	37.33
50	25.33	30.67	38.67	53.00
75	52.67	58.00	71.33	94.00
100	84.00	100.00	100.00	100.00
LSD (P=0.05)	1.22	1.09	1.42	1.60
LSD (P=0.01)	1.65	1.47	1.92	2.16

Each value is a mean of five replicates.

Table 12: Effect of different levels of fly ash on penetration of *M. incognita* (500 juveniles) in roots of okra cv. Long Green.

Fly ash level (%)	Per cent penetration of *M. incognita* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	125	25.0	166	33.2	220	44.0	261	52.2
5	102	20.4	132	26.4	173	34.6	202	40.4
10	93	18.6	112	22.4	152	30.4	189	37.8
20	80	16.0	107	21.4	142	28.4	177	35.8
30	74	14.8	98	19.6	122	24.4	146	29.2
40	68	13.6	80	16.0	107	21.4	121	24.2
50	55	11.0	61	12.2	72	14.4	95	19.0
75	-	-	02	0.4	06	1.2	10	2.0
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	6.39		7.21		8.01		9.31	
LSD (P=0.01)	8.63		9.87		11.2		12.72	

Each value is a mean of five replicates.

(Fig.10). The penetration was found concentration dependent, as the concentration was increased the penetration was decreased.

Similar results were also observed in penetration of *M. javanica* juveniles in the roots of okra (Table 13). Where highest penetration was found in control 50.4% at 7th day and lowest was 1.4% at 75% level. However, at 100% level the penetration of juveniles was completely checked in all days (Table 13).

The numbers of penetrated juveniles of *M. incognita* were slightly higher than *M. javanica* at all the levels in all days (Fig. 10).

Experiments 7 and 8

Effect of Fly Ash on Penetration of *M. incognita* and *M. javanica* Juveniles in Cucumber Roots

The results presented in table 14 shows that fly ash was toxic to nematodes at all the levels (5, 10, 20, 30, 40, 50, 75 and 100%). All the concentrations of fly ash significantly (P=0.05 and P=0.01) suppressed the penetration of *M. incognita* juveniles in cucumber roots compared to control at all time intervals (1st, 3rd, 5th and 7th day). Penetration of the juveniles was inversely proportional to fly ash concentrations. The highest penetration was found in control (48.8%) and lowest at 75% level (1.0%) on 7th day (Fig. 11). At 100% level no penetration was observed from 1st day to 7th day.

Similarly the penetration of juveniles of *M. javanica* in cucumber roots was also suppressed significantly (P=0.05 and P=0.01) at all levels

Table 13: Effect of different levels of fly ash on penetration of *M. javanica* (500 juveniles) in roots of okra cv. Long Green.

Fly ash level (%)	Per cent penetration of *M. javanica* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	116	23.2	157	31.4	211	42.2	252	50.4
5	98	19.6	127	25.4	169	33.8	198	39.6
10	90	18.0	108	21.6	147	29.4	185	37.0
20	75	15.0	103	20.6	138	27.6	172	34.4
30	70	14.0	94	18.8	117	23.4	140	28.0
40	64	12.8	76	15.2	103	20.6	116	23.2
50	51	10.2	57	11.4	66	13.2	91	18.2
75	-	-	01	0.2	04	0.8	07	1.4
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	5.23		6.73		9.84		12.02	
LSD (P=0.01)	7.10		9.15		13.37		16.16	

Each value is a mean of five replicates.

Table 14: Effect of different levels of fly ash on penetration of *M. incognita* (500 juveniles) in roots of cucumber cv. Poona Kheera.

Fly ash level (%)	Per cent penetration of *M. incognita* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)		Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	108	21.6	153	30.6	205	41.0	244	48.8
5	88	17.6	103	20.6	145	29.0	181	36.2
10	79	15.8	98	19.6	137	27.4	171	34.2
20	66	13.2	93	18.6	125	25.0	158	31.6
30	58	11.6	79	15.8	97	19.4	119	23.8
40	55	11.0	65	13.0	85	17.0	99	19.8
50	48	9.6	55	11.0	68	13.6	81	16.2
75	-	-	-	-	02	0.4	05	1.0
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	4.2		5.21		6.71		11.21	
LSD (P=0.01)	5.7		7.12		9.12		15.33	

Each value is a mean of five replicates.

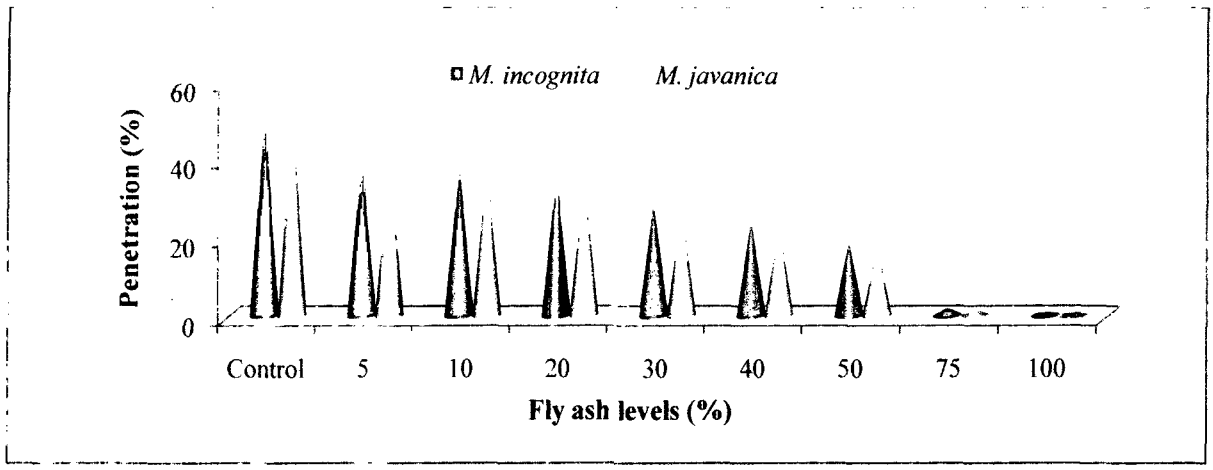


Fig.10: Effect of different fly ash levels on penetration of juveniles in okra root after 7th day.

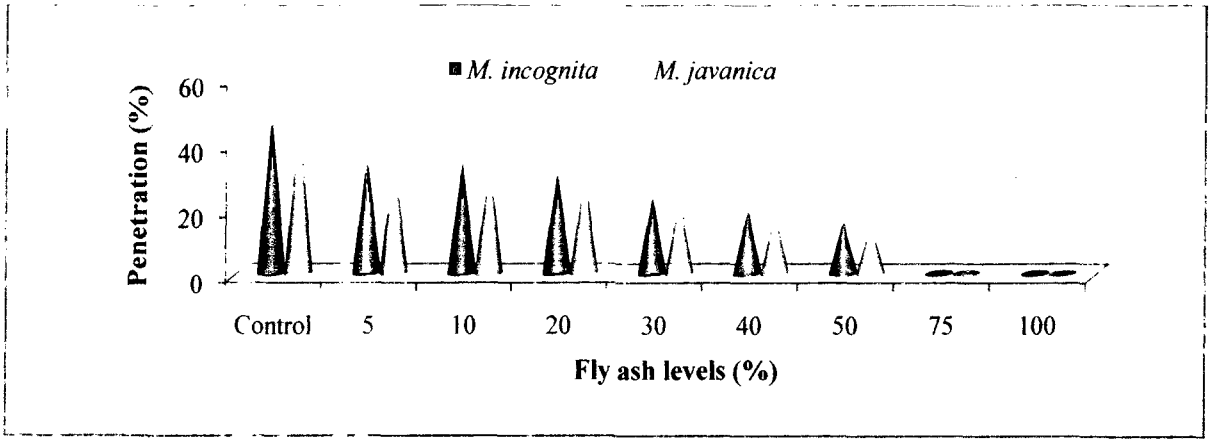


Fig.11: Effect of different fly ash levels on penetration of juveniles in cucumber root after 7th day.

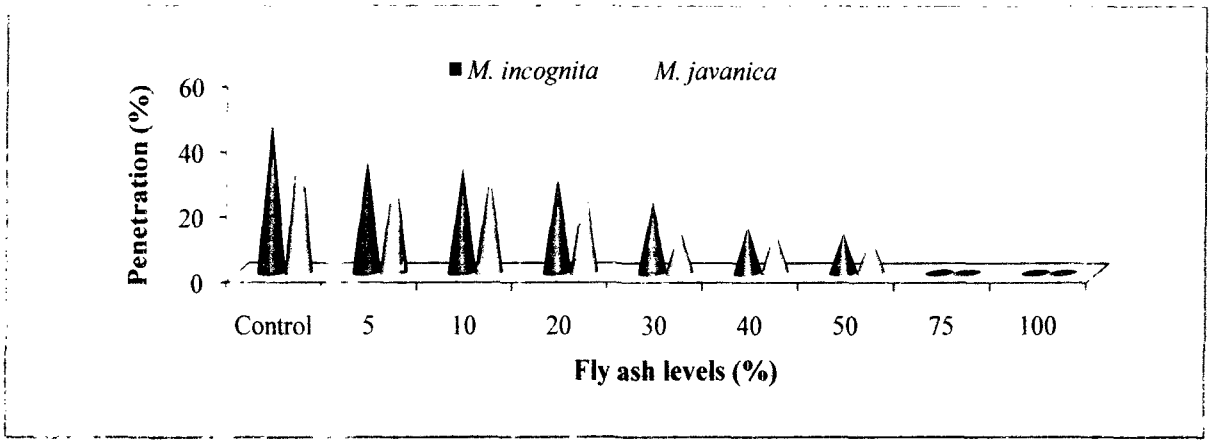


Fig.12: Effect of different fly ash levels on penetration of juveniles in pepper root after 7th day.

of fly ash (Table 15). Where highest penetration was observed in control (48.0%) and lowest (0.8%) at 75% level on 7th day. There was no penetration at 100% level.

However, juveniles of *M. javanica* were slightly more affected as compared to *M. incognita* at all time intervals (Fig. 11).

Experiments 9 and 10

Effect of Fly Ash on Penetration of *M. incognita* and *M. javanica* Juveniles in Pepper Roots

Data presented in table 16 shows that all the levels (5, 10, 20, 30, 40, 50, 75 and 100%) of fly ash in soil were harmful to juveniles of *M. incognita*. The penetration was inversely proportional to fly ash level. As the concentration of fly ash increased the penetration of juveniles decreased. All the levels of fly ash significantly (P=0.05 and P=0.01) suppressed the penetrations of *M. incognita* in pepper roots as compared to control at all time intervals. The highest penetration was found in control i.e. 47.8% and lowest (0.6%) was observed at 75% on 7th day (Fig. 12). At 100% level no penetration was observed (Table 16).

Similar results were also observed in penetration of *M. javanica* juveniles in pepper roots (Table 17), where highest penetration was found in control (46.8%) and lowest (0.4%) at 75% level on 7th day. At 100% level, none of the juveniles penetrated in roots. However, penetration of juveniles of *M. incognita* was slightly more as compared to *M. javanica* at all the levels in all days (Fig. 12).

Table 15: Effect of different levels of fly ash on penetration of *M. javanica* (500 juveniles) in roots of cucumber cv. Poona Kheera.

Fly ash level (%)	Per cent penetration of *M. javanica* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	105	21.0	149	29.8	200	40.0	240	48.0
5	84	16.8	99	19.8	142	28.4	177	35.4
10	77	15.4	93	18.6	133	26.6	166	33.2
20	61	12.2	88	17.6	121	24.4	153	30.6
30	52	10.4	79	15.8	93	18.6	116	23.2
40	50	10.0	61	12.2	82	16.4	94	18.8
50	42	8.4	50	10.0	63	2.6	77	15.4
75	-	-	-	-	01	0.2	04	0.8
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	5.23		6.73		9.13		15.31	
LSD (P=0.01)	7.10		9.15		12.21		21.45	

Each value is a mean of five replicates.

Table 16: Effect of different levels of fly ash on penetration of *M. incognita* (500 juveniles) in roots of pepper cv. Suryamukhi Green.

Fly ash level (%)	Per cent penetration of *M. incognita* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	105	21.0	149	29.8	199	39.8	239	47.8
5	75	15.0	99	19.8	140	28.0	176	35.2
10	70	14.0	86	17.2	131	26.2	164	32.8
20	61	12.2	75	15.0	121	24.2	151	30.2
30	50	10.0	60	12.0	89	17.8	113	22.6
40	42	8.4	51	10.2	62	12.4	73	14.6
50	35	7.0	42	8.4	50	10.0	61	12.2
75	-	-	-	-	-	-	03	0.6
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	4.71		8.02		9.12		16.21	
LSD (P=0.01)	6.46		11.13		12.18		22.33	

Each value is a mean of five replicates.

Table 17: Effect of different levels of fly ash on penetration of *M. javanica* (500 juveniles) in roots of pepper cv. Suryamukhi Green.

Fly ash level (%)	Per cent penetration of *M. javanica* juveniles							
	1st day		3rd day		5th day		7th day	
	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)	Mean	Penetration (%)
Control	101	20.2	143	28.6	194	38.8	234	46.8
5	71	14.2	92	18.4	133	26.6	169	33.8
10	64	12.8	83	16.6	124	24.8	157	31.4
20	55	11.0	72	14.4	110	22.0	141	28.2
30	47	9.4	52	10.4	65	13.0	71	14.2
40	35	7.0	48	9.6	56	11.2	68	13.6
50	29	5.8	34	6.8	44	8.8	57	11.4
75	-	-	-	-	-	-	02	0.4
100	-	-	-	-	-	-	-	-
LSD (P=0.05)	6.34		5.25		8.21		13.32	
LSD (P=0.01)	8.52		7.37		11.35		18.15	

Each value is a mean of five replicates.

Experiments 11 and 12

Effect of Fly Ash on Development of *M. incognita* and *M. javanica* Juveniles in Okra Roots

The data presented in table 18 show that the development of juveniles of *M. incognita* was significantly (P=0.05 and P=0.01) suppressed in all the fly ash amended soils (5, 10, 20, 30, 40, 75%) in the roots of okra in all the weeks. However, none of the juveniles penetrated/developed at 100% fly ash level.

In first week the J2 developed to J3/J4 stage at all the fly ash levels (5, 10, 20, 30, 40, 50 and 75%) except at 100% level, where none of the juveniles was penetrated the roots. From 5% to 75% levels, the number of J3/J4 stages were significantly (P=0.05 and P=0.01) low as compared to control. But none of the premature or mature females were found in the first week.

In second week, J2 developed into premature female through J3/J4 stages up to 40% level, however their number were decreased as levels of fly ash increased. Few mature females were also developed to mature stage in control and 5% level only.

In third week, all penetrated juveniles transformed either into J3/J4 or premature or mature female stages up to 20% level. The number of premature female was more as compared to J3/J4. At higher levels (30, 40, 50 and 75%), several juveniles were still at J2 stage, although few

Table 18: Effect of different levels of fly ash on the development of *M. incognita* (1000 juveniles) in roots of okra cv. Long Green.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	145	388	-	-	124	144	113	32	-	160	194	71	-	-	94	138
5	162	338	-	-	123	134	106	14	-	143	175	26	-	-	77	40
10	204	218	-	-	148	109	76	-	-	138	157	18	-	-	34	14
20	224	178	-	-	160	98	51	-	-	136	140	12	-	14	25	-
30	268	98	-	-	172	84	32	-	120	106	87	-	18	76	18	-
40	261	72	-	-	148	117	18	-	109	157	28	-	25	99	17	-
50	250	67	-	-	143	106	-	-	101	140	24	-	29	130	12	-
75	63	20	-	-	82	16	-	-	30	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	7.8	20.6			1.75	6.7				9.8	11.1				8.6	
(P=0.01)	10.6	27.9			2.37	9.2				13.3	15.0				11.7	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

juveniles reached up to premature stage at 30% to 50% level but none was developed to mature stage.

In fourth week, some of the J3/J4 juveniles transformed to premature stage and from premature to mature stages up to 10% levels, whereas none of the juveniles developed to mature stage onward this level. However, several individuals were still at J2 or J3/J4 stages at higher levels of fly ash (30, 40 and 50%).

Similar results of developmental stages of *M. javanica* juveniles were also observed in roots of okra (Table 19). However, all the developed stages of *M. incognita* juveniles were slightly greater in number than *M. javanica* in okra roots.

Experiments 13 and 14

Effect of Fly Ash on Development of *M. incognita* and *M. javanica* Juveniles in Cucumber Roots

Results given in table 20, show that all the ratios of fly ash and soil (5:95, 10:90, 20:80, 30:70, 40:60, 50:50, 75:25 and 100:00) were harmful for the development of *M. incognita* juveniles. The development of juveniles was significantly (P=0.05 and P=0.01) suppressed in all the fly ash and soil mixtures in cucumber roots in all the weeks, except at 100% level. At 100% level, none of the juveniles was penetrated the roots of cucumber at any time intervals (1^{st}, 2^{nd}, 3^{rd} and 4^{th} week), consequently no development was observed.

Table 19: Effect of different levels of fly ash on the development of *M. javanica* (1000 juveniles) in roots of okra cv. Long Green.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	142	386	-	-	121	140	112	30	-	158	192	69	-	-	93	137
5	160	336	-	-	120	131	104	12	-	142	172	24	-	-	75	38
10	201	216	-	-	147	106	75	-	-	135	156	16	-	-	32	13
20	222	176	-	-	158	96	49	-	-	133	139	10	-	12	22	_
30	266	96	-	-	169	82	30	-	118	104	85	-	16	74	16	-
40	260	70	-	-	146	116	16	-	107	155	26	-	22	98	16	-
50	248	65	-	-	141	105	-	-	99	138	22	-	27	128	10	-
75	60	19	-	-	80	14	-	-	28	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	11.0	24.7			2.5	5.2				7.2	12.8				8.6	
(P=0.01)	14.9	33.4			3.4	7.1				9.8	17.3				11.7	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

Table 20: Effect of different levels of fly ash on the development of *M. incognita* (1000 juveniles) in roots of cucumber cv. Poona Kheera.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	138	382	-	-	118	136	108	26	-	152	188	64	-	-	88	133
5	156	332	-	-	116	128	100	08	-	138	168	20	-	-	72	34
10	198	213	-	-	144	101	71	-	-	130	153	14	-	-	30	11
20	218	170	-	-	155	92	44	-	-	126	130	08	-	10	20	-
30	260	92	-	-	165	78	26	-	112	102	82	-	13	71	14	-
40	256	68	-	-	143	113	13	-	104	151	24	-	19	95	12	-
50	245	61	-	-	138	101	-	-	96	134	20	-	24	124	08	-
75	155	16	-	-	76	10	-	-	25	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	12.2	22.7			1.1	4.2				6.0	11.1				7.8	
(P=0.01)	16.3	30.7			1.5	5.7				8.3	15.2				10.6	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

The J2 developed to J3/J4 stage at all levels of fly ash (5, 10, 20, 30, 40, 50 and 75%) (Figs. 13 and 14), however their number were less as compared to control in the first week. In this week, neither premature nor mature females were found.

In second week, J2 developed into J3/J4 stages, from J3/J4 stages to premature female (Fig. 15) up to 40% level of fly ash, however their number were low as compared to control. Few premature females transformed into mature stage in control and 5% level (Fig. 16).

In third week, the premature females were greater than other stages up to 20% level. While some of the juveniles transformed into mature stage in control, 5%, 10%, and 20% levels. In rest of the levels, none of the juveniles reached to mature stage. However, some of the juveniles were still at J2 stage at higher levels (30% to 75% levels).

In fourth week, all the J3/J4 stages transformed to premature and premature to mature stages in control, whereas very few juveniles changed into mature stage in 5% and 10% levels. Onward 20% to 50% levels, many juveniles were still remained in J2 or J3/J4 stages, although few juveniles reached up to premature stage. But at 75% and 100% levels, none of the juveniles succeeded in the roots of cucumber crop. Generally a delay in development of juveniles was noticed by all the treatments as compared to control.

Similar pattern of development of *M. javanica* juveniles were found in cucumber roots (Table 21). However, slightly less number of *M.*

Fig.13: J2 stage

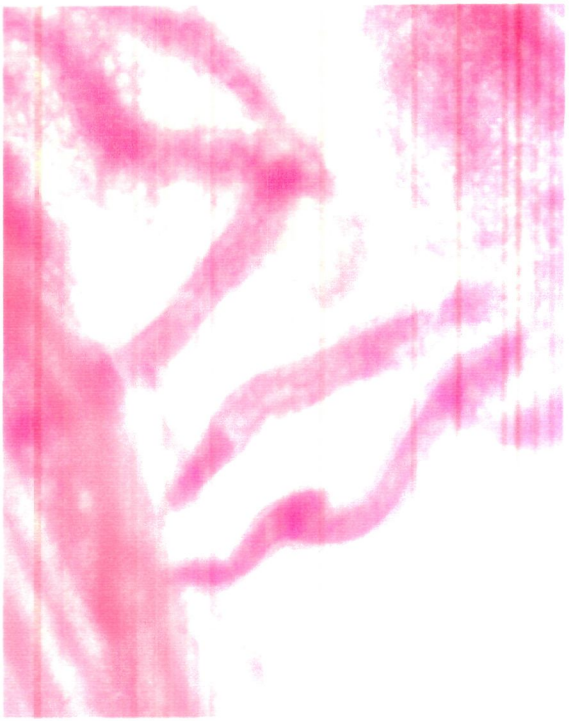


Fig.14: J3/J4 stage

Fig.15: Premature female

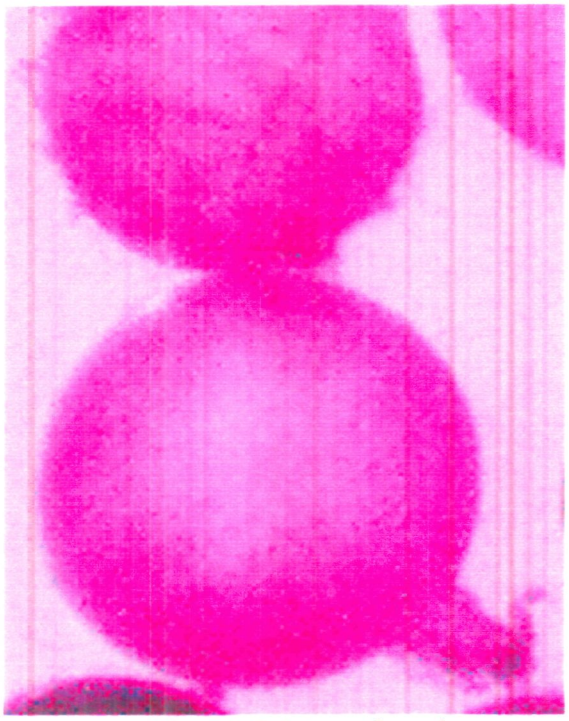


Fig.16: Mature female

Different stages of juveniles of root-knot nematodes.

Table 21: Effect of different levels of fly ash on the development of *M. javanica* (1000 juveniles) in roots of cucumber cv. Poona Kheera.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	136	380	-	-	115	134	106	24	-	149	185	62	-	-	84	130
5	155	330	-	-	113	126	98	06	-	137	167	19	-	-	70	32
10	197	212	-	-	140	98	68	-	-	128	152	12	-	-	28	10
20	216	168	-	-	154	91	42	-	-	124	128	06	-	09	18	-
30	258	89	-	-	162	76	25	-	108	99	80	-	12	68	12	-
40	255	66	-	-	140	112	12	-	101	149	22	-	17	93	10	-
50	244	59	-	-	136	98	-	-	95	133	19	-	22	122	07	-
75	153	14	-	-	74	08	-	-	24	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	10.9	18.6			1.2	5.4				7.3	11.2				6.2	
(P=0.01)	15.1	25.1			1.6	7.3				9.9	15.3				8.4	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

javanica juveniles penetrated/transformed into different stages as compared to *M. incognita.*

Experiments 15 and 16

Effect of Fly Ash on Development of *M. incognita* and *M. javanica* Juveniles in Pepper Roots

It is evident from table 22 that all the levels of fly ash (5, 10, 20, 30, 40, 50, 75 and 100%) were influenced to *M. incognita* juveniles. The development of juveniles significantly (P=0.05 and P=0.01) decreased in all the levels of fly ash compared to control in all the weeks.

In first week, J2 changed into J3/J4 stages in control as well as up to 75% level of fly ash. However, their numbers were decreased as the level of fly ash increased. Hence, maximum juveniles were observed in control. None of the juveniles was observed at 100% level.

In second week, J2 developed into J3/J4 stage and from J3/J4 stage into premature female up to 40% level of fly ash, few mature females were also observed in control and 5% level. However at 50 and 75% levels all the juveniles were still remained into J2 or J3/J4 stages. At 100% level of fly ash the development of juveniles was completely checked.

In third week all the J2 stage juveniles transformed either into J3/J4 or premature/mature female stages up to 20% level. In rest of the levels, none of the juveniles reached to mature stages in pepper roots. While,

Table 22: Effect of different levels of fly ash on the development of *M. incognita* (1000 juveniles) in roots of pepper cv. Suryamukhi Green.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	132	378	-	-	110	132	103	22	-	146	182	58	-	-	77	128
5	151	324	-	-	106	122	94	05	-	134	165	17	-	-	64	28
10	195	209	-	-	138	96	66	-	-	126	148	10	-	-	26	09
20	215	165	-	-	153	89	40	-	-	122	126	05	-	7	15	-
30	254	84	-	-	156	71	22	-	105	96	78	-	11	66	09	-
40	253	63	-	-	137	108	10	-	99	146	20	-	14	88	08	-
50	238	55	-	-	134	95	-	-	90	130	17	-	18	118	05	-
75	145	12	-	-	72	06	-	-	22	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	12.3	23.1			2.5	6.0				5.5	11.2				3.2	
(P=0.01)	17.1	31.2			3.6	8.2				7.9	15.5				4.7	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

Table 23: Effect of different levels of fly ash on the development of *M. javanica* (1000 juveniles) in roots of pepper cv. Suryamukhi Green.

Fly ash level (%)	Developmental stages (One week)				Developmental stages (Two week)				Developmental stages (Three week)				Developmental stages (Four week)			
	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀	J2	J3/J4	P♀	M♀
Control	128	372	-	-	106	127	101	19	-	142	178	53	-	-	75	125
5	147	320	-	-	102	120	92	03	-	133	160	15	-	-	62	26
10	193	208	-	-	135	94	64	-	-	124	146	08	-	-	24	07
20	212	161	-	-	151	87	38	-	-	120	125	03	-	05	12	-
30	250	80	-	-	147	66	17	-	102	93	75	-	10	65	08	-
40	248	58	-	-	136	104	08	-	98	141	18	-	12	85	06	-
50	236	52	-	-	131	92	-	-	88	128	15	-	16	115	04	-
75	139	10	-	-	70	05	-	-	20	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(P=0.05)	11.7	25.4			2.8	4.6				5.3	12.5				8.6	
(P=0.01)	16.8	34.3			3.9	6.3				7.6	17.0				11.7	

Each value is a mean of five replicates. J= Juveniles; P♀= Premature female; M♀= Mature female.

many juveniles were still remained in J2 stage from 30 to 75% level of fly ash.

In fourth week, all the J3/J4 juveniles developed to premature stage and from premature to mature stage in control, whereas very few developed up to mature stage at 5% and 10% levels. From 20% level onwards none of the individual was reached to mature stage. However, at 75 and 100% levels none of the juveniles was found in the roots of pepper plant in 4^{th} week (Table 22).

Similar results of development of *M. javanica* juveniles were also observed in pepper roots (Table 23), whereas numbers of individuals of *M. javanica* were slightly less than the individuals of *M. incognita* at any level or week.

SECTION-III

Experiment 17

Effect of Fly Ash Application on Okra Plant

The data given in Table 24 reveal that all the parameters of plant growth (length, fresh wt, dry wt of root and shoot, leaf number, leaf area) and yield (flower/plant, fruit/plant) of okra were increased significantly (P=0.05 and P=0.01) upto 30% level of fly ash compared to control set. However, all above parameters were increased maximum at 20% level of fly ash (Fig. 17). At 40% level, all the parameters were at par with control. However, at higher concentrations (50, 75 and 100%) all the

Table 24: Effect of different levels of fly ash on plant growth performance, yield and photosynthetic pigments of okra cv. Long Green.

Treatment FA(%)	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	30.0	38.0	3.8	15.0	1.0	3.7	20	92	13	09	0.821	0.405	1.226	0.366
5	33.2	41.4	4.2	17.2	1.1	4.3	23	94	16	11	0.826	0.407	1.233	0.374
10	36.4	44.0	5.5	19.5	1.4	4.9	26	96	19	13	0.842	0.403	1.245	0.410
20	42.8	49.6	6.8	22.8	1.7	5.7	33	104	25	17	0.887	0.437	1.324	0.419
30	38.2	46.5	5.8	20.8	1.5	5.2	29	98	22	15	0.885	0.434	1.319	0.412
40	29.5	37.2	3.5	14.6	0.9	3.7	19	91	12	08	0.820	0.401	1.221	0.358
50	25.0	33.0	2.8	10.5	0.7	2.6	16	86	10	06	0.802	0.380	1.182	0.356
75	20.3	28.5	2.2	8.2	0.6	2.1	12	80	07	03	0.785	0.386	1.143	0.343
100	16.2	22.2	1.8	5.0	0.5	1.1	08	68	04	01	0.775	0.342	1.117	0.382
(P=0.05)	1.57	1.42	0.2	0.93	0.02	0.3	1.2	1.1	1.5	1.2	0.003	0.001	0.004	0.006
(P=0.01)	2.14	1.97	0.3	1.27	0.03	0.4	1.6	1.5	2.1	1.7	0.004	0.002	0.006	0.008

Each value is a mean of five replicates. FA = Fly ash; Cart. = Carotenoids.

parameters were significantly (P=0.05 and P=0.01) reduced. The reduction was directly proportional to fly ash levels.

Similar results were also observed for chlorophyll pigments (chl. a, chl. b and total chlorophyll a+b) and carotenoids. Highest chlorophyll content was found in 20% level of fly ash, (Table 24), while minimum was observed in 100% of fly ash level (Fig. 17).

Experiment 18

Effect of Fly Ash Application and *M. incognita* on Okra Plant

Table 25 shows that the growth and yield parameters of okra were increased significantly in 10, 20 and 30% levels of fly ash + *M. incognita* combinations compared to uninoculated control set in general. The maximum increase in all parameters was observed at 20% level of fly ash + *M. incognita* combination (Fig. 18). At 5% and 40% + *M. incognita* combinations, some of the parameters were at par when compared to control. But plant growth and yield parameters in higher levels (50% + Mi, 75% + Mi and 100% + Mi combinations) were reduced significantly (P=0.05 and P=0.01) compared to control set (Table 25).

Similar pattern of increase/decrease in photosynthetic pigments (chl. a, chl. b, chl. a+b and carotenoids) of okra were also observed in all fly ash + *M. incognita* treatments when compared to control set. However, maximum increment was found at 20% fly ash + *M. incognita* combination (Fig. 18).

Table 25: Effect of different levels of fly ash and *M. incognita* (5000 juveniles) on plant growth performance, yield and photo-synthetic pigments of okra cv. Long Green.

Treatment FA+Mi	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	30.0	38.0	3.8	15.0	1.0	3.7	20	92	13	09	0.821	0.405	1.226	0.366
Inoculated	13.8	18.6	1.3	3.8	0.3	0.9	05	63	02	00	0.651	0.329	0.980	0.306
5%+Mi	29.2	37.0	3.4	14.4	0.9	3.6	20	88	11	07	0.816	0.390	1.206	0.340
10%+Mi	33.0	40.2	5.1	16.6	1.0	4.0	23	90	15	10	0.832	0.395	1.227	0.350
20%+Mi	39.2	46.1	6.0	19.5	1.5	4.9	29	100	21	15	0.878	0.430	1.308	0.386
30%+Mi	36.0	43.4	5.2	18.0	1.3	4.5	25	95	16	13	0.875	0.426	1.301	0.380
40%+Mi	28.8	36.5	3.0	13.7	0.8	3.4	17	86	10	06	0.815	0.386	1.204	0.342
50%+Mi	24.7	32.8	2.6	10.2	0.7	2.6	15	85	09	05	0.800	0.380	1.178	0.350
75%+Mi	20.1	28.2	2.0	8.0	0.5	2.0	12	79	06	03	0.782	0.381	1.143	0.340
100%+Mi	16.0	22.0	1.7	4.7	0.4	1.0	07	66	04	01	0.772	0.340	1.112	0.380
(P=0.05)	0.8	1.1	0.6	0.4	0.1	0.2	1.4	1.56	1.62	0.8	0.004	0.009	0.007	0.008
(P=0.01)	1.1	1.5	0.9	0.6	0.2	0.3	2.8	2.14	2.18	1.2	0.006	0.012	0.010	0.011

Each value is a mean of five replicates. FA = Fly ash; Mi = *M. incognita*; Cart. = Carotenoids.

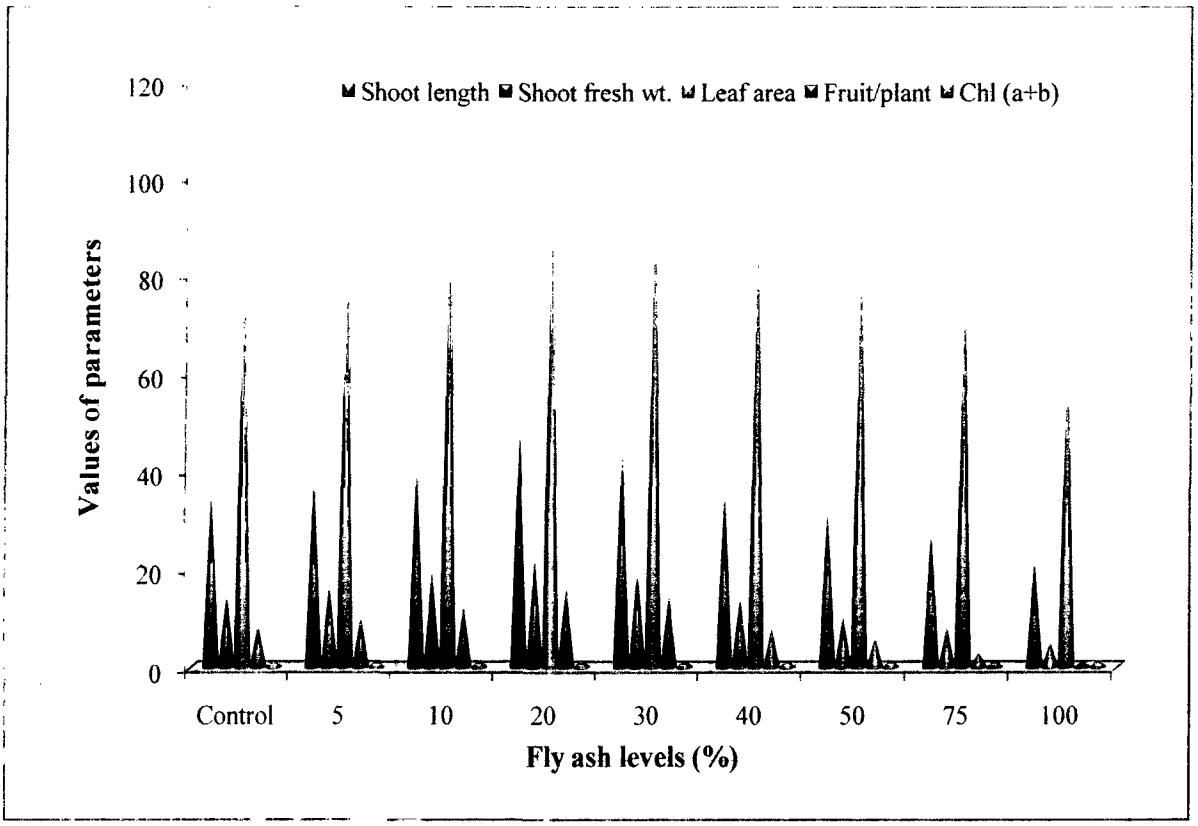


Fig.17: Effect of different fly ash levels on okra cv. Long Green.

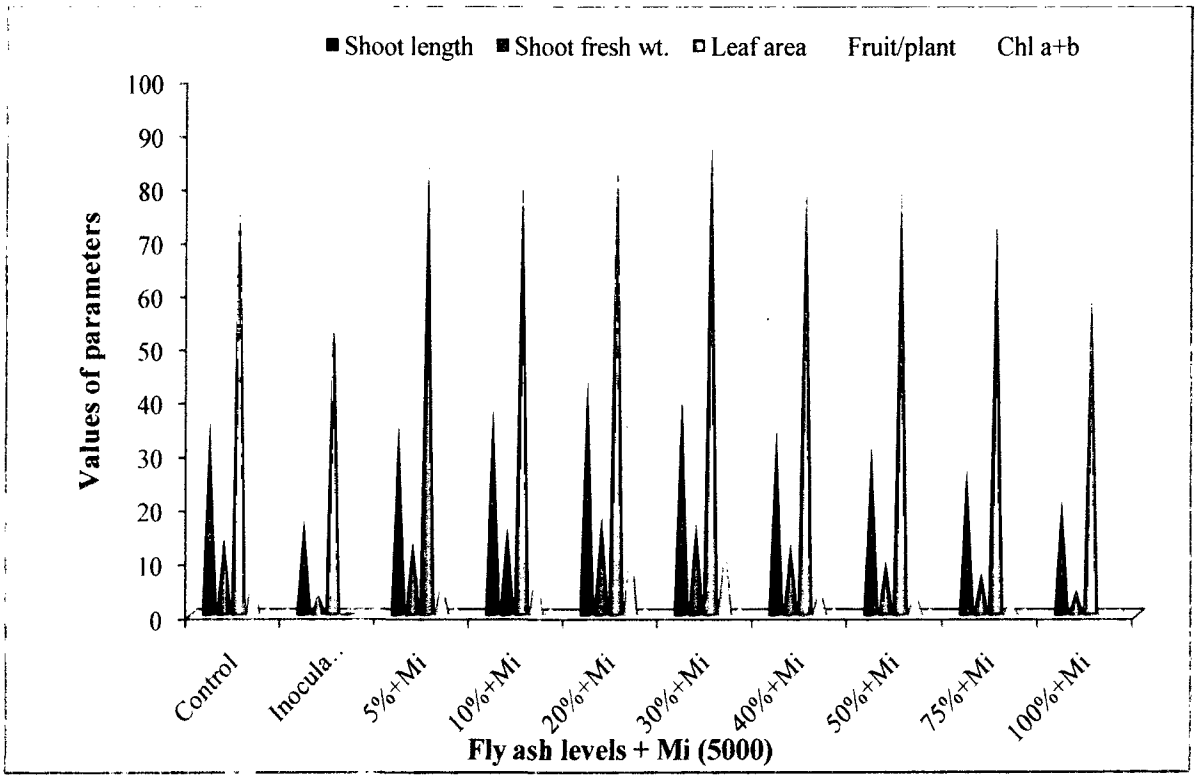


Fig.18: Effect of different fly ash levels and *M. incognita* on okra cv. Long Green.

When growth, yield and photosynthetic pigments in different fly ash + Mi combinations were compared to inoculated set (nematode alone), it was observed that all parameters were increased significantly (P=0.05 and P=0.01) except in 100% + Mi combination, where some of the parameters were at par to inoculated set (Fig. 18).

Experiment 19

Effect of Fly Ash Application and *M. javanica* on Okra Plant

The data presented in table 26 also indicate that in combined treatments of fly ash and *M. javanica* the plant growth and yield were increased significantly from 10 to 30% levels compared to uninoculated control in general (Fig. 19). Thus maximum growth was observed in 20% fly ash + *M. javanica* combination, whereas at 5% level, all the parameters were at par with uninoculated control set. At higher combinations from 40% onward, a significant (P=0.05 and P=0.01) decrease was observed in all these parameters.

The data summarized in table 26 show that all photosynthetic pigments (chl.a, chl. b, total chl. a+b and carotenoids) were significantly increased at 10 to 30% combined treatments (Fig. 19). Maximum increase was observed at 20% + Mj combination. However, at 5% and from 40 to 100% + nematode combinations, all photosynthetic pigments were reduced (Table 26).

When plant growth, yield and photosynthetic pigments in all fly ash + nematode combinations were compared to inoculated set, it was

Table 26: Effect of different levels of fly ash and *M. javanica* (5000 juveniles) on plant growth performance, yield and photo-synthetic pigments of okra cv. Long Green.

Treatment FA+Mj	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	30.0	38.0	3.8	15.0	1.0	3.7	20	92	13	09	0.821	0.405	1.226	0.366
Inoculated	14.5	19.2	1.5	4.0	0.4	1.0	06	65	03	00	0.660	0.328	0.988	0.308
5%+Mj	29.8	37.6	3.6	14.7	0.9	3.7	21	90	12	08	0.820	0.394	1.214	0.354
10%+Mj	33.5	40.8	4.3	17.0	1.1	4.1	24	91	16	11	0.838	0.398	1.236	0.360
20%+Mj	39.6	46.5	6.2	19.8	1.6	5.2	30	101	22	16	0.882	0.432	1.314	0.392
30%+Mj	36.5	44.0	5.5	18.2	1.4	4.6	26	96	18	14	0.878	0.430	1.308	0.385
40%+Mj	29.0	36.8	3.2	14.0	0.8	3.5	18	87	11	07	0.816	0.392	1.208	0.347
50%+Mj	24.8	32.9	2.7	10.4	0.7	2.6	15	85	10	06	0.801	0.380	1.180	0.355
75%+Mj	20.2	28.4	2.0	8.1	0.5	2.1	12	80	06	03	0.784	0.385	1.148	0.340
100%+Mj	16.0	22.0	1.7	4.8	0.4	1.1	07	67	04	01	0.775	0.340	1.115	0.380
(P=0.05)	0.31	0.93	0.2	0.3	0.07	0.2	0.93	1.5	1.2	0.9	0.003	0.009	0.012	0.004
(P=0.01)	0.42	1.27	0.3	0.4	0.10	0.3	1.27	2.1	1.6	1.3	0.004	0.013	0.016	0.006

Each value is a mean of five replicates. FA = Fly ash; Mj = *M. javanica*; Cart. = Carotenoids.

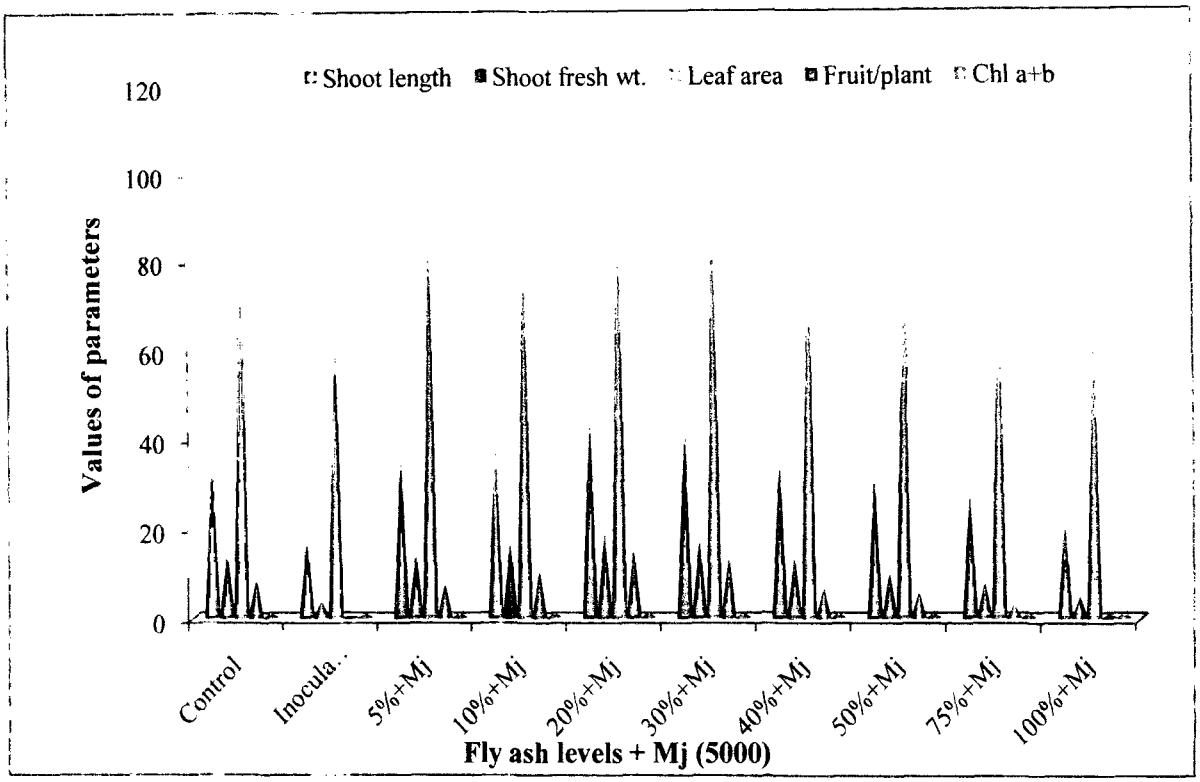


Fig.19: Effect of different fly ash levels and *M. javanica* on okra cv. Long Green.

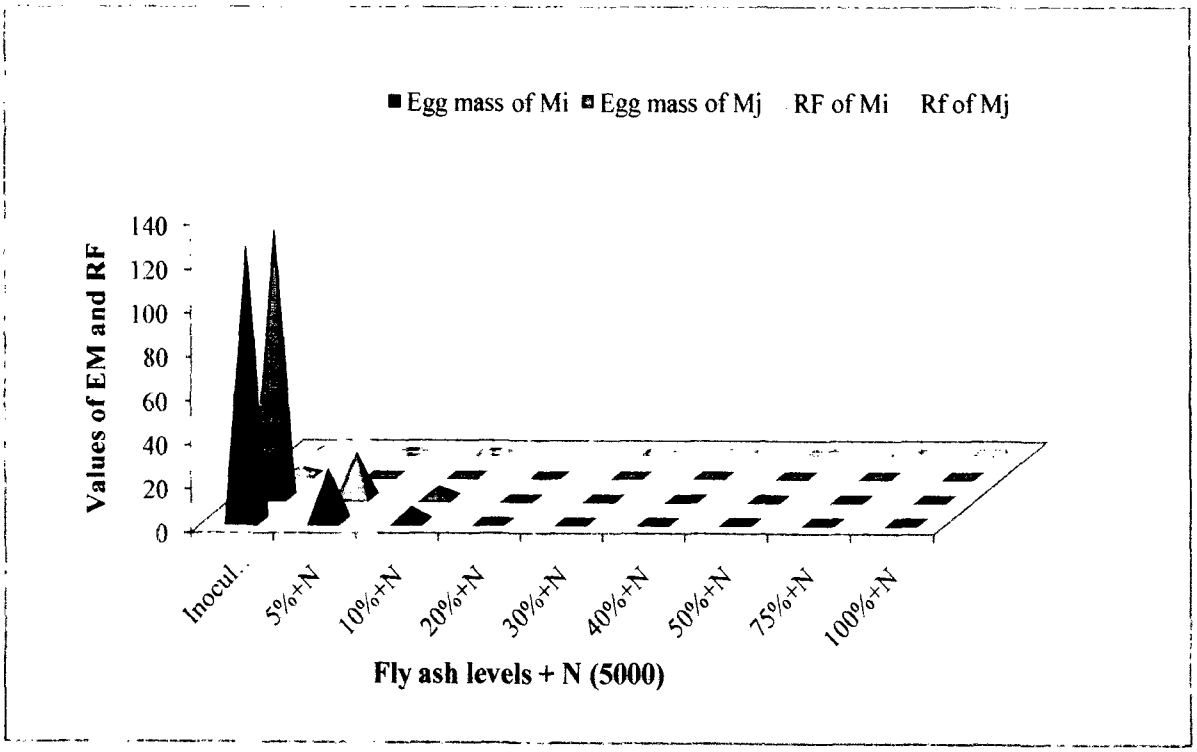


Fig.20: Effect of different fly ash levels on egg mass (EM) and reproduction factor (Rf) of *M. incognita* (Mi) and *M. javanica* (Mj) juveniles in okra roots.

observed that all parameters were significantly (P=0.05 and P=0.01) increased except in 100% + Mj combination (Table 26 and Fig. 19).

Effect of Fly Ash on Disease Intensity and Reproduction Factor of *M. incognita* and *M. javanica* on Okra Plant

The results presented in the table 27, show that disease intensity in terms of gall index and egg mass index of *M. incognita* and *M. javanica* was highest in inoculated control set followed by nematodes with 5% and 10% levels of fly ash (Fig. 20). While in rest of the combinations none of the galls or egg masses were produced. The number of larvae and consequently reproduction factors of *M. incognita* and *M. javanica* were highest in inoculated set (control) followed by 5% and 10% combinations. The reproduction factor of *M. incognita* was greater than *M. javanica* in control as well as at 5% and 10% levels of fly ash. However, reproduction in rest of the levels with either nematode was nil (Fig. 20).

Experiment 20

Effect of Fly Ash Application on Cucumber Plant

Data presented in table 28 show that the application of fly ash in soil was beneficial for the plant growth and yield of cucumber at lower levels (from 5 to 30%). The length, fresh weight, dry weight of root and shoot, leaf/plant, leaf area were increased significantly (P=0.05 and P=0.01) from 5 to 30% levels of fly ash in comparison to control, maximum being at 20% level of fly ash (Fig. 21). Whereas, at 40% level,

Table 27: Effect of fly ash on disease intensity and reproduction factor of *M. incognita* and *M. javanica* (5000 juveniles) on okra cv. Long Green.

Treatment FA(%)+N	*M. incognita*				*M. javanica*			
	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction Factor (Rf)	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction factor (Rf)
Control (Inoculated)	5-5/5-5	130	21734	4.35	5-5/5-5	127	20731	4.15
5%+N	1-4/1-3	25	1580	0.32	1-4/1-2	22	1475	0.30
10%+N	1-3/0-3	7	540	0.11	1-3/0-2	6	510	0.10
20%+N	-	-	-	-	-	-	-	-
30%+N	-	-	-	-	-	-	-	-
40%+N	-	-	-	-	-	-	-	-
50%+N	-	-	-	-	-	-	-	-
75%+N	-	-	-	-	-	-	-	-
100%+N	-	-	-	-	-	-	-	-

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; GI = Gall index; EMI = Egg mass index.

Table 28: Effect of different levels of fly ash on plant growth performance, yield and photosynthetic pigments of cucumber cv. Poona Kheera.

Treatment FA(%)	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	41.0	49.5	5.6	21.5	1.4	5.4	22	116	17	10	0.932	0.481	1.413	0.455
5	44.2	52.2	6.2	22.6	1.6	5.7	24	120	20	13	0.944	0.490	1.434	0.476
10	47.0	55.2	7.1	23.5	1.8	5.9	28	124	23	16	0.962	0.492	1.454	0.486
20	53.4	60.8	8.4	24.8	2.1	6.2	36	130	30	22	0.992	0.515	1.507	0.511
30	50.0	57.5	7.6	24.0	1.9	6.0	32	126	27	18	0.985	0.498	1.483	0.498
40	40.8	49.2	5.4	21.2	1.4	5.3	20	115	16	09	0.930	0.480	1.410	0.450
50	33.0	40.6	3.8	17.5	1.0	4.4	16	106	12	06	0.912	0.469	1.381	0.436
75	26.8	34.5	3.3	14.6	0.8	3.7	12	100	08	03	0.897	0.438	1.335	0.430
100	20.0	25.4	2.8	10.4	0.7	2.6	08	94	04	0	0.868	0.435	1.303	0.395
(P=0.05)	1.79	0.98	0.3	0.52	0.04	0.07	0.9	1.5	1.2	1.1	0.002	0.005	0.012	0.007
(P=0.01)	2.43	1.34	0.4	0.71	0.05	0.10	1.2	2.1	1.7	1.5	0.003	0.008	0.016	0.010

Each value is a mean of five replicates. FA = Fly ash; Cart. = Carotenoids.

all the parameters were at par with control. Then gradually, these parameters were significantly declined at higher levels of fly ash (from 50 to 100%).

The yield of cucumber in terms of flower/plant and fruit/plant was also increased significantly (P=0.05 and P=0.01) from 5% to 30% levels (Fig. 21). The highest increase in yield was recorded at 20% level of fly ash (Table 28). However, it was at par with control in 40% treatment. Onwards 50% level, a sharp decline was noticed (Table 28).

Table 28 also shows that chlorophyll contents (chl. a, chl. b, total chl. a+b and carotenoids) were increased from 5 to 30% levels and onwards 40 % level, these parameters were declined. All photosynthetic pigments were recorded highest at 20% level, upto the extent of 0.992, 0.515, 1.507 and 0.511 mg/g in chl.a, chl. b, total chl. a+b and carotenoids respectively (Fig. 21).

Experiment 21

Effect of Fly Ash Application and *M. incognita* on Cucumber Plant

Data presented in table 29 reveal that cucumber crop showed variable growth responses to different levels of fly ash amended soil + *M. incognita* combination. A significant increase (P=0.05 and P=0.01) in plant growth in terms of length, fresh weight, dry weight, leaf area and leaf number was observed from 10 to 30% combinations, as compared to uninoculated and control sets. However, some of the parameters in 5% and 40% combinations of fly ash + nematode were at par compared to

Table 29: Effect of different levels of fly ash and *M. incognita* (5000 juveniles) on plant growth performance, yield and photo-synthetic pigments of cucumber cv. Poona Kheera.

Treatment FA+Mi	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	41.0	49.5	5.6	21.5	1.4	5.4	22	116	17	10	0.932	0.481	1.143	0.455
Inoculated	16.4	21.5	1.8	7.8	0.4	1.9	05	90	02	00	0.757	0.380	1.130	0.330
5%+Mi	40.0	48.8	5.0	20.8	1.2	5.2	18	114	15	08	0.925	0.462	1.387	0.419
10%+Mi	43.0	51.4	6.4	21.8	1.6	5.4	25	120	21	13	0.948	0.476	1.424	0.433
20%+Mi	51.2	58.0	7.5	23.9	1.9	5.9	32	127	27	18	0.975	0.502	1.478	0.459
30%+Mi	47.0	55.3	7.0	23.3	1.7	5.8	29	123	24	16	0.968	0.478	1.450	0.445
40%+Mi	39.8	48.5	4.8	20.6	1.2	5.1	17	113	14	07	0.920	0.450	1.370	0.430
50%+Mi	32.7	40.4	3.7	17.5	0.9	4.4	15	105	11	05	0.908	0.462	1.368	0.420
75%+Mi	26.7	34.2	3.2	14.4	0.8	3.6	11	99	07	02	0.893	0.433	1.326	0.390
100%+Mi	19.8	25.2	2.7	10.2	0.7	2.5	08	93	03	00	0.865	0.425	1.290	0.381
(P=0.05)	1.10	0.52	0.4	0.98	0.2	0.2	2.1	2.17	2.4	1.6	0.007	0.012	0.152	0.021
(P=0.01)	1.49	0.71	0.6	1.34	0.3	0.3	2.9	2.96	3.2	2.2	0.010	0.016	0.207	0.029

Each value is a mean of five replicates. FA = Fly ash; Mi = *M. incognita*; Cart. = Carotenoids.

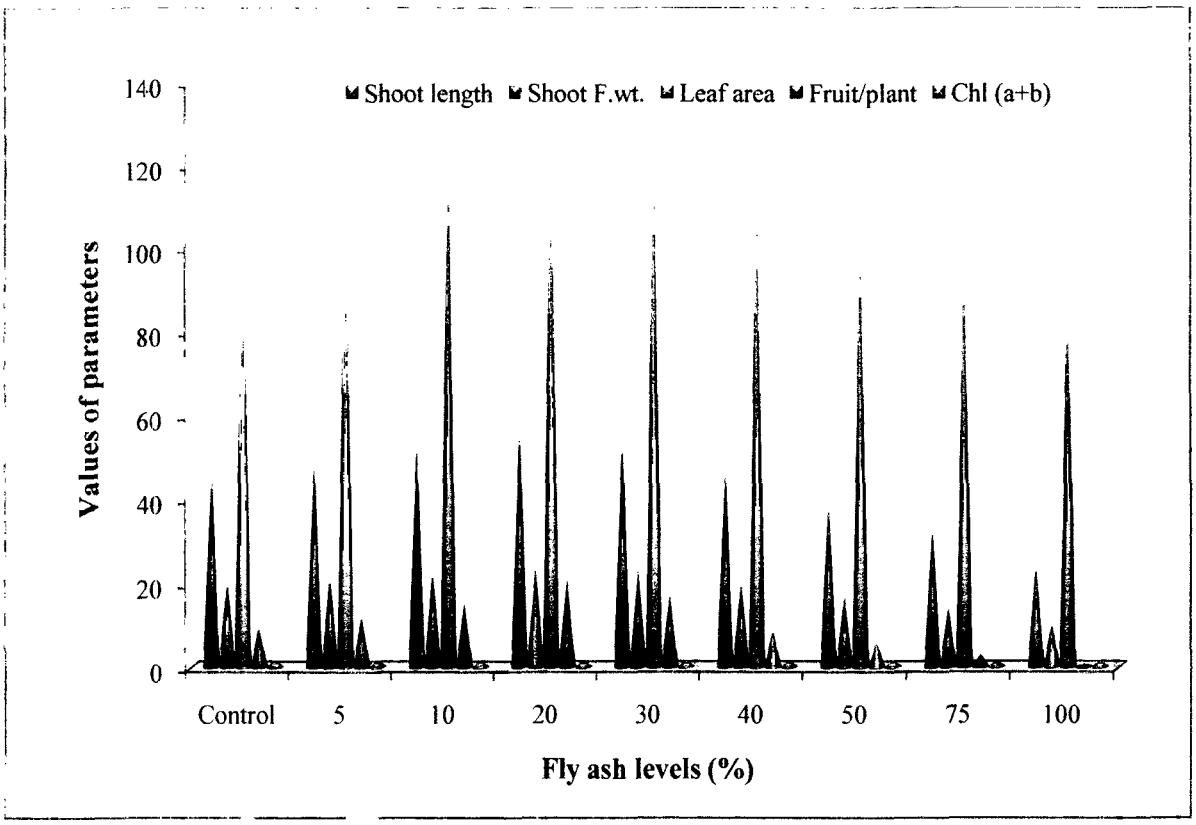


Fig.21: Effect of different fly ash levels on cucumber cv. Poona Kheera.

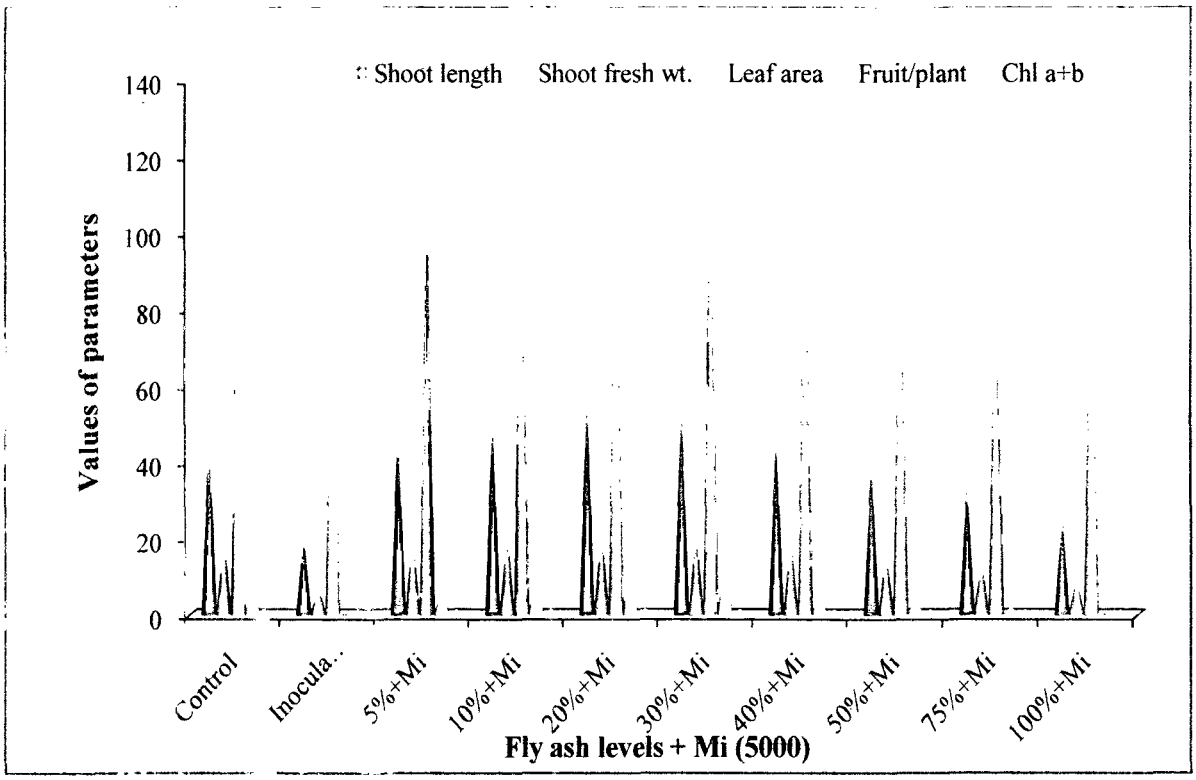


Fig.22: Effect of different fly ash levels and *M. incognita* on cucumber cv. Poona Kheera.

control set. From 50 to 100% levels, there were marked reductions in all these parameters. Highest increase in all the above parameters was recorded at 20% fly ash + *M. incognita* combination and lowest was found in 100% fly ash + *M. incognita* combination (Fig. 22). However, all the growth parameters were significantly better in all combinations than inoculated set (Table 29). Similar results were also observed for yield attributes (Fig. 22).

Table 29 also shows that photosynthetic pigments of leaves were gradually increased with the increase in the levels of fly ash + *M. incognita* combinations. Significant increase in chl.a, chl.b, total chl. (a+b) and carotenoids was recorded in general from 10 to 30% levels, highest being at 20% level of fly ash + *M. incognita.* There was marked reduction in chl. a, chl. b, total chl. (a+b) and carotenoids in rest of the combinations compared to control (Fig. 22).

Experiment 22

Effect of Fly Ash Application and *M. javanica* on Cucumber Plant

Data summarized in table 30 reveal that in the combined effect of fly ash and *M. javanica*, the growth and yield were also increased significantly from 10 to 30% levels compared to control. Highest increase was observed at 20% + Mj combination (Fig. 23). However, at 5 and 40% + nematode combinations, some of the parameters were at par with control. The plant growth and yield were reduced in rest of the combinations (Table 30).

Table 30: Effect of different levels of fly ash and *M. javanica* (5000 juveniles) on plant growth performance, yield and photo-synthetic pigments of cucumber cv. Poona Kheera.

Treatment FA+Mj	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	41.0	49.5	5.6	21.5	1.4	5.4	22	116	17	10	0.932	0.481	1.413	0.455
Inoculated	17.5	22.4	2.0	8.2	0.5	2.1	06	92	03	00	0.775	0.386	1.143	0.343
5%+Mj	40.2	49.0	5.2	21.0	1.3	5.3	19	115	16	09	0.928	0.470	1.408	0.430
10%+Mj	43.3	51.8	6.6	22.2	1.7	5.6	26	121	22	14	0.952	0.480	1.432	0.440
20%+Mj	51.8	58.5	7.8	24.0	2.0	6.0	33	128	28	19	0.980	0.510	1.490	0.505
30%+Mj	47.2	55.8	7.1	23.8	1.8	5.9	30	124	25	17	0.975	0.486	1.461	0.472
40%+Mj	40.0	48.8	5.0	20.8	1.2	5.2	18	114	15	08	0.924	0.462	1.386	0.438
50%+Mj	32.8	40.5	3.7	17.5	0.9	4.4	15	105	11	06	0.910	0.465	1.375	0.422
75%+Mj	26.6	34.3	3.3	14.5	0.8	3.6	11	99	07	02	0.895	0.435	1.330	0.392
100%+Mj	19.8	25.3	2.7	10.3	0.7	2.6	08	94	04	00	0.865	0.426	1.291	0.383
(P=0.05)	1.07	0.86	0.4	0.5	0.2	0.14	1.3	1.16	1.28	1.7	0.011	0.006	0.007	0.010
(P=0.01)	1.98	1.17	0.6	0.7	0.3	0.20	1.7	1.56	1.73	2.3	0.015	0.009	0.010	0.013

Each value is a mean of five replicates. FA = Fly ash; Mj = *M. javanica*; Cart. = Carotenoids.

Similar pattern of effect of soil application of fly ash and *M. javanica* combinations were observed in all photosynthetic pigments (chl.a, chl.b, total chl.a+b and carotenoids). Photosynthetic pigments were significantly increased from 10 to 30% combinations and maximum at 20 % combination. However, at 5 and 50% to 100% combinations, all photosynthetic pigments were reduced (Table 30).

When growth performance in terms of growth, yield and photosynthetic pigments were compared to inoculated set (nematode alone), all the parameters were found highly significant in all the treatments except in 100% + Mj combination, where some of the parameters were at par to inoculated set (Fig. 23).

Effect of Fly Ash on Disease Intensity and Reproduction Factor of *M. incognita* and *M. javanica* on Cucumber Plant

Results given in table 31 reveal that all the levels of fly ash influenced the disease intensity in terms of gall index and egg mass index. Highest disease intensity was noticed in control set and lowest was in 10% level of fly ash caused by both the nematodes. While, in other higher levels (from 20 to 100%) none of the galls and egg masses were produced by any nematode in cucumber plant (Fig. 24). The reproduction factor of *M. incognita* in control set as well as in 5% and 10% combinations, was greater than *M. javanica*. However, reproduction in both nematodes was not observed in rest of the combinations (Fig. 24).

Table 31: Effect of fly ash on disease intensity and reproduction factor of *M. incognita* and *M. javanica* (5000 juveniles) on cucumber cv. Poona Kheera.

Treatment FA(%)+N	*M. incognita*				*M. javanica*			
	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction Factor (Rf)	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction factor (Rf)
Control (Inoculated)	5-5/5-5	125	19544	3.91	5-5/5-5	114	18342	3.67
5%+N	1-4/0-3	20	1250	0.25	1-4/0-2	18	1050	0.21
10%+N	1-3/0-2	5	447	0.09	1-3/0-1	4	400	0.08
20%+N	-	-	-	-	-	-	-	-
30%+N	-	-	-	-	-	-	-	-
40%+N	-	-	-	-	-	-	-	-
50%+N	-	-	-	-	-	-	-	-
75%+N	-	-	-	-	-	-	-	-
100%+N	-	-	-	-	-	-	-	-

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; GI = Gall index; EMI = Egg mass index.

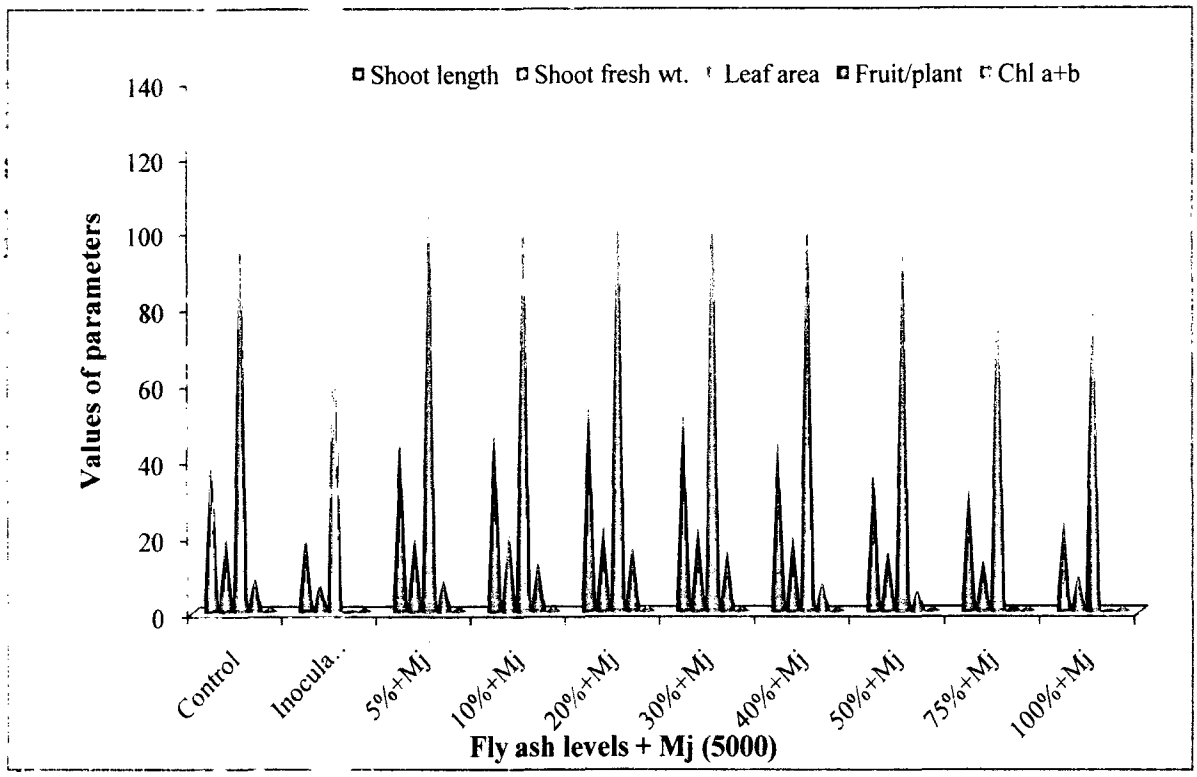


Fig.23: Effect of different fly ash levels and *M. javanica* on cucumber cv. Poona Kheera.

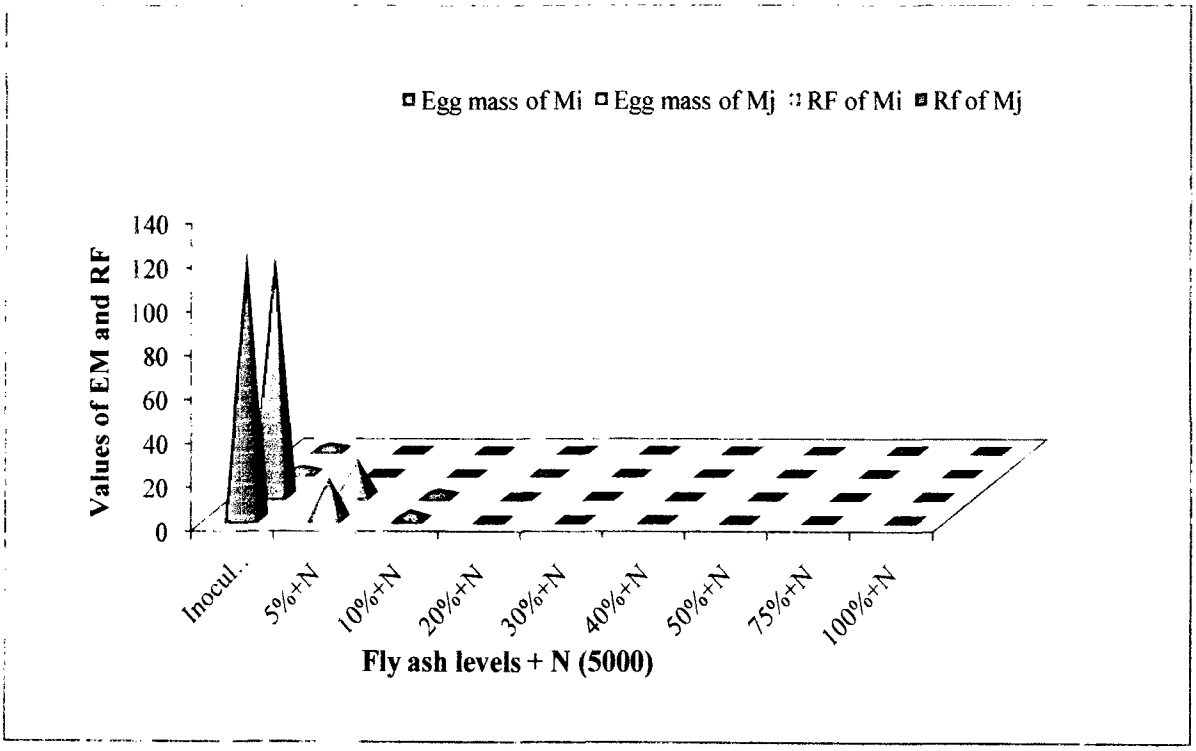


Fig.24: Effect of different fly ash levels on egg mass (EM) and reproduction factor (Rf) of *M. incognita* (Mi) and *M. javanica* (Mj) juveniles in cucumber roots.

Experiment 23

Effect of Fly Ash Application on Pepper Plant

Results given in table 32 shows that the application of fly ash amended soil was beneficial for the plant growth and yield of pepper at lower levels. Plant growth in terms of length, fresh wt, day wt of shoot and root; leaf/plant and leaf area as well as yield in terms of flower/plant, fruit/plant were increased significantly (P=0.05 and P=0.01) from 5 to 30 % levels of fly ash in comparison to control set. Maximum increase in these parameters was found at 20% level of fly ash (Fig. 25). However, at 40% level, all the parameters were at par with control. After that all parameters were reduced significantly in rest of the fly ash mixtures (50, 75 and 100%). The reduction was directly proportional to the fly ash levels.

Similarly photosynthetic pigments (chl.a, chl.b, chl.a+b and carotenoids) increased upto 30% treatment, maximum being at 20% treatment (Table 32). However, only chl. a was at par with control in 40 % treatments. Onwards, 40% level a sharp decline was noticed (Fig. 25).

Experiment 24

Effect of Fly Ash Application and *M. incognita* on Pepper Plant

The data given in table 33 show that in the combined treatment of fly ash and *M. incognita*, the growth and yield parameters were also increased significantly (P=0.05 and P=0.01) from 10 to 30% levels compared to control set (uninoculated). Highest increase was observed at

Table 32: Effect of different levels of fly ash on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

Treatment FA(%)	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	16.7	30.9	3.0	8.9	0.8	2.3	69	17	07	05	0.757	0.386	1.143	0.349
5	19.5	33.5	3.5	9.4	0.9	2.4	74	19	09	07	0.772	0.390	1.162	0.353
10	22.2	36.5	4.1	10.0	1.0	2.5	79	22	11	09	0.785	0.393	1.178	0.357
20	27.2	42.0	5.5	11.8	1.4	3.0	88	28	18	14	0.831	0.409	1.240	0.372
30	25.4	39.2	4.9	10.8	1.2	2.7	84	26	14	11	0.802	0.396	1.182	0.359
40	16.5	30.5	2.8	8.7	0.7	2.2	68	16	06	04	0.750	0.378	1.120	0.341
50	13.6	26.2	2.3	7.5	0.6	1.9	62	13	04	02	0.722	0.343	1.062	0.306
75	10.7	22.4	2.0	6.8	0.5	1.7	57	10	01	00	0.689	0.332	1.021	0.295
100	8.8	16.0	1.6	5.6	0.4	1.4	49	07	00	00	0.660	0.328	0.988	0.291
(P=0.05)	1.16	1.27	0.2	0.2	0.01	0.03	2.5	0.8	0.7	0.8	0.007	0.002	0.012	0.002
(P=0.01)	1.56	1.70	0.3	0.3	0.02	0.04	3.6	1.1	1.0	1.1	0.010	0.003	0.016	0.003

Each value is a mean of five replicates. FA = Fly ash; Cart. = Carotenoids.

Table 33: Effect of different levels of fly ash and *M. incognita* (5000 juveniles) on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

Treatment FA+Mi	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	16.7	30.9	3.0	8.9	0.8	2.3	69	17	07	05	0.757	0.386	1.143	0.349
Inoculated	7.0	14.6	1.0	4.9	0.3	1.2	40	05	00	00	0.620	0.301	0.921	0.264
5%+Mi	16.2	30.2	2.5	8.5	0.6	2.1	66	15	05	03	0.740	0.370	1.110	0.333
10%+Mi	19.5	33.2	3.4	9.4	0.8	2.3	73	18	09	07	0.770	0.380	1.150	0.344
20%+Mi	26.0	41.0	4.7	11.0	1.1	2.7	83	24	13	10	0.808	0.389	1.197	0.355
30%+Mi	22.5	36.2	4.1	10.2	1.0	2.6	77	22	11	08	0.778	0.380	1.158	0.341
40%+Mi	16.0	30.0	2.3	8.1	0.6	2.0	65	14	04	02	0.731	0.362	1.093	0.325
50%+Mi	13.5	26.0	2.2	7.4	0.5	1.8	61	12	03	01	0.720	0.337	1.057	0.300
75%+Mi	10.4	22.1	2.0	6.7	0.4	1.7	56	10	01	00	0.686	0.330	1.020	0.293
100%+Mi	8.7	16.0	1.5	5.5	0.3	1.3	48	06	00	00	0.658	0.325	0.983	0.288
(P=0.05)	1.21	0.80	0.4	0.3	0.2	0.17	3.1	1.7	1.33	1.2	0.012	0.008	0.007	0.004
(P=0.01)	1.63	1.12	0.6	0.4	0.3	0.23	4.7	2.3	1.81	1.6	0.016	0.011	0.010	0.005

Each value is a mean of five replicates. FA = Fly ash; Mi = *M. incognita*; Cart. = Carotenoids.

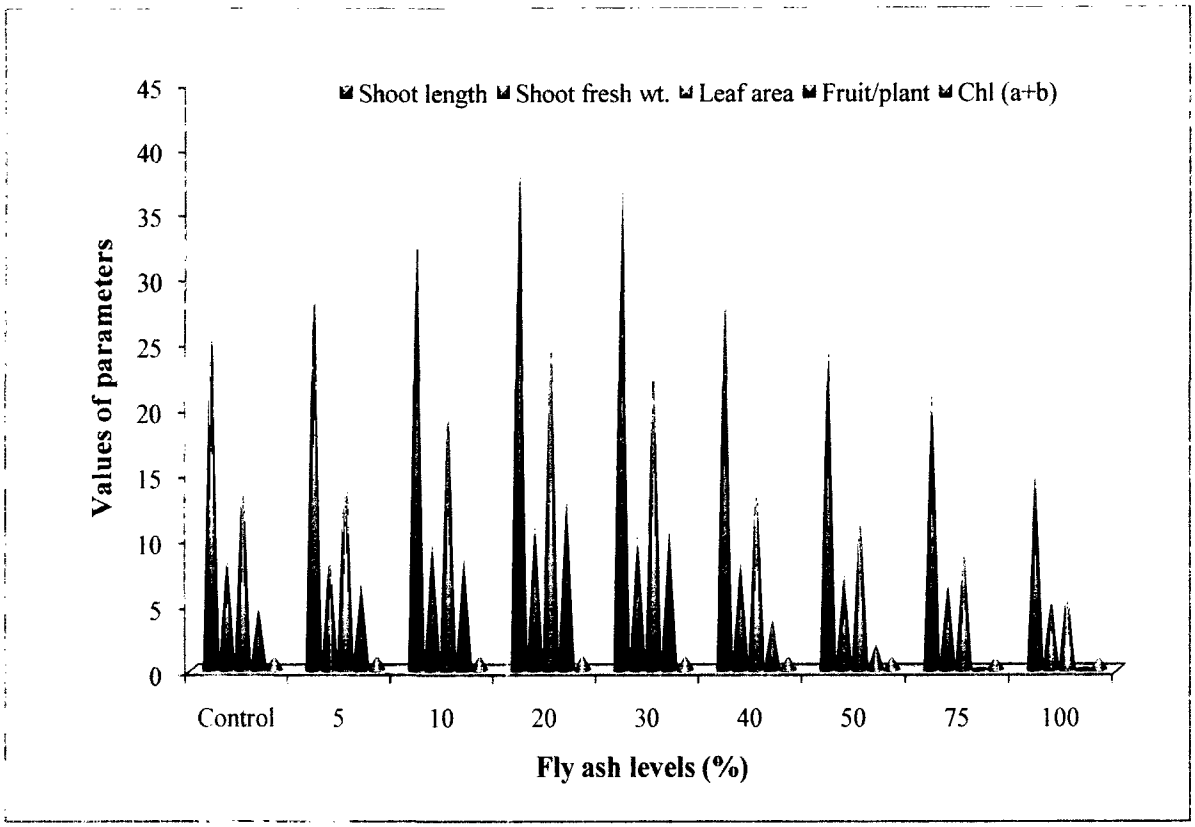


Fig.25: Effect of different fly ash levels on pepper cv. Suryamukhi Green.

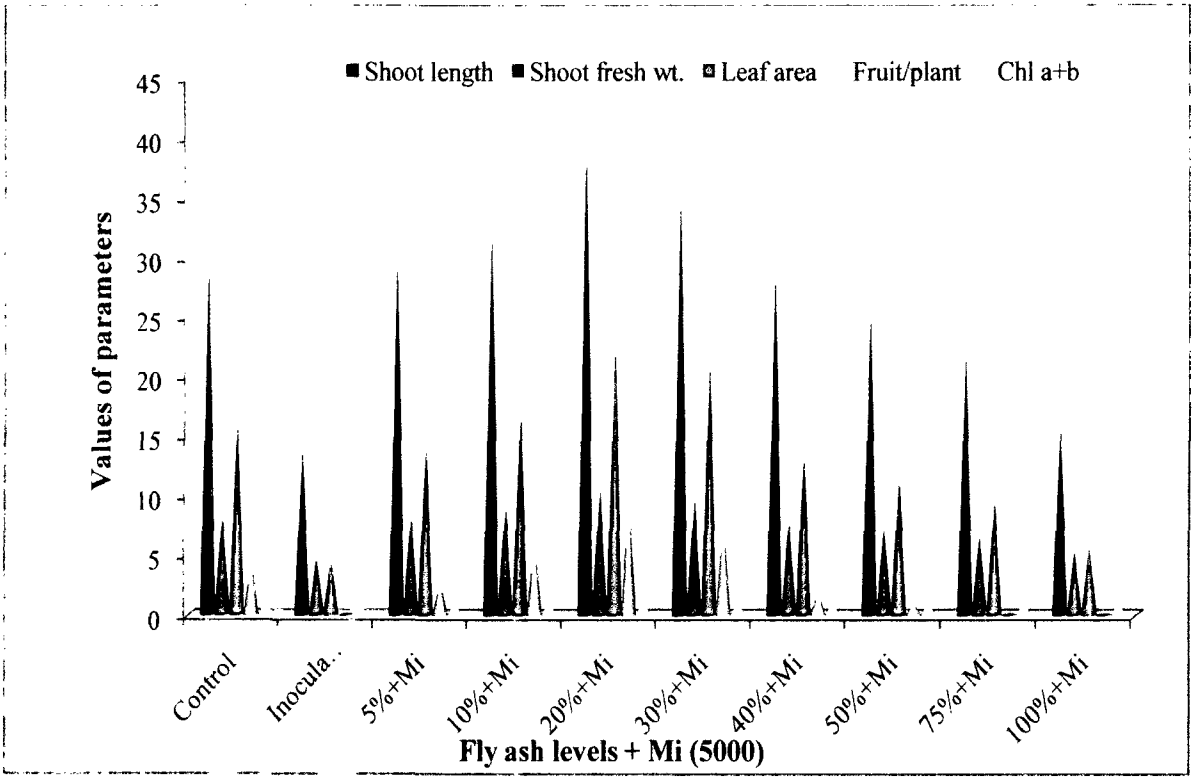


Fig.26: Effect of different fly ash levels and *M. incognita* on pepper cv. Suryamukhi Green.

20% fly ash + *M. incognita* combination (Fig. 26). However, at 5 and 40 % nematode combinations, all parameters were at par with control. In rest of the combinations, all parameters declined gradually and significantly (P=0.05 and P=0.01).

Similar results were also observed for photosynthetic pigments (chl. a, chl. b, total chl. a+b and carotenoids) in general (Fig. 26).

When plant growth, yield and photosynthetic pigments in all treatments were compared to inoculated set (nematode alone), all the parameters were found highly significant (P=0.05 and P=0.01), except in 100% + Mi combination, where plant growth and yield parameters were at par to inoculated set. Maximum increased was observed at 20% combinations (Table 33 and Fig. 26).

Experiment 25

Effect of Fly Ash Application and *M. javanica* on Pepper Plant

The data given in table 34 reveal that all the growth and yield parameters of pepper were increased significantly from 10 to 30% combination of fly ash + *M. javanica* compared to control set. Maximum growth was observed at 20% combination. While, at 5 and 40%, most of the above parameters were at par with control set. However, in 50 to 100 % level of fly ash + *M. javanica* combinations, these parameters were declined significantly (Fig. 27).

Table 34: Effect of different levels of fly ash and *M. javanica* (5000 juveniles) on plant growth performance, yield and photo-synthetic pigments of pepper cv. Suryamukhi Green.

Treatment FA+Mj	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	16.7	30.9	3.0	8.9	0.8	2.3	69	17	07	05	0.757	0.386	1.143	0.349
Inoculated	7.9	15.5	1.2	5.2	0.3	1.3	42	06	00	00	0.632	0.319	0.951	0.282
5%+Mj	16.5	30.5	2.7	8.6	0.7	2.2	67	16	06	04	0.748	0.380	1.128	0.343
10%+Mj	19.8	33.5	3.6	9.6	0.9	2.4	74	20	10	08	0.778	0.388	1.158	0.351
20%+Mj	26.5	41.2	4.9	11.2	1.2	2.8	84	25	14	11	0.820	0.398	1.218	0.362
30%+Mj	22.8	36.7	4.3	10.4	1.1	2.6	79	23	12	09	0.790	0.388	1.176	0.350
40%+Mj	16.2	30.1	2.5	8.4	0.6	2.1	66	15	05	03	0.742	0.370	1.112	0.333
50%+Mj	13.5	26.0	2.2	7.4	0.5	1.9	61	12	03	01	0.720	0.340	1.060	0.304
75%+Mj	10.5	22.2	2.0	6.7	0.4	1.7	56	10	01	00	0.688	0.332	1.020	0.395
100%+Mj	8.7	16.0	1.5	5.5	0.3	1.4	48	06	00	00	0.660	0.325	0.985	0.288
(P=0.05)	0.9	1.7	0.2	0.4	0.13	0.09	2.2	1.2	0.8	1.7	0.009	0.008	0.012	0.007
(P=0.01)	1.2	2.3	0.3	0.5	0.18	0.12	2.9	1.6	1.1	2.3	0.012	0.011	0.016	0.010

Each value is a mean of five replicates. FA = Fly ash; Mj = *M. javanica*; Cart. = Carotenoids.

Similar, pattern of combined effect of fly ash and *M. javanica* was noticed on photosynthetic pigments (chl. a, chl. b, total chl. a+b and carotenoids) of pepper plant (Fig. 27).

When effect of fly ash + *M. javanica* treatments on plant growth and yield were compared to inoculated set (nematode alone), it was observed that all parameters were significantly increased in all the treatments (5% to 75% + Mj) except in 100% + Mj combination, where all parameters were at par to inoculated set. However, all photosynthetic pigments were increased significantly (P=0.05 and P=0.01) in all combinations (from 5% to 100% + Mj) and highest increment was observed at 20 % level of fly ash + Mj combination (Table 34 and Fig. 27).

Effect of Fly Ash on Disease Intensity and Reproduction Factor of *M. incognita* and *M. javanica* on Pepper Plant

The data presented in table 35 show that disease intensity in terms of gall index and egg mass index was maximum in inoculated control set followed by 5 and 10% level of fly ash. However, in rest of the combinations none of the galls or egg masses was produced by any nematode. The reproduction factor of *M. incognita* was higher than *M. javanica* in control, 5% and 10% levels of fly ash. However reproduction was nil at higher levels (onwards 20% + N combination) (Fig. 28).

Table 35: Effect of fly ash on disease intensity and reproduction factor of *M. incognita* and *M. javanica* (5000 juveniles) on pepper cv. Suryamukhi Green.

Treatment FA(%)+N	*M. incognita*				*M. javanica*			
	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction factor (Rf)	Disease intensity (GI/EMI)	No. of Egg mass	No. of larvae	Reproduction factor (Rf)
Control (Inoculated)	1-5/1-5	115	14832	2.97	1-5/1-5	105	14012	2.80
5%+N	1-4/0-2	14	870	0.17	1-3/0-2	11	800	0.16
10%+N	1-2/0-2	3	310	0.06	1-2/0-1	2	250	0.05
20%+N	-	-	-	-	-	-	-	-
30%+N	-	-	-	-	-	-	-	-
40%+N	-	-	-	-	-	-	-	-
50%+N	-	-	-	-	-	-	-	-
75%+N	-	-	-	-	-	-	-	-
100%+N	-	-	-	-	-	-	-	-

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; GI = Gall index; EMI = Egg mass index.

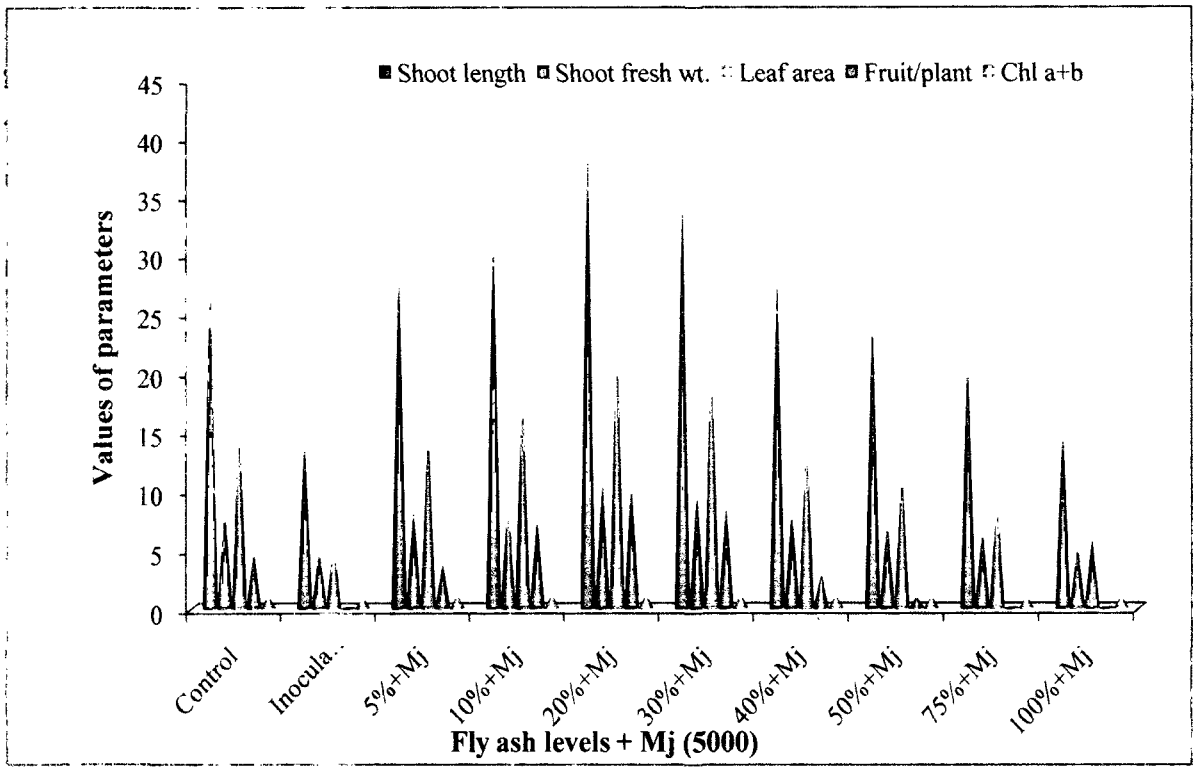


Fig.27: Effect of different fly ash levels and *M. javanica* on pepper cv. Suryamukhi Green.

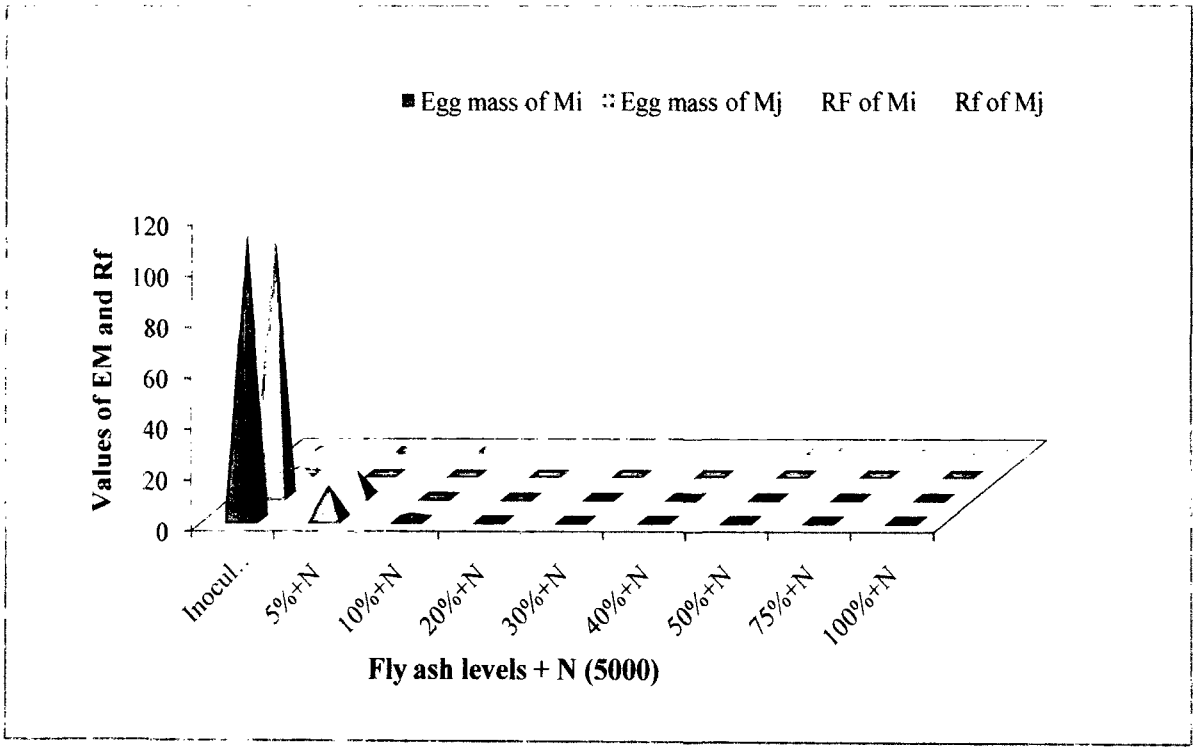


Fig.28: Effect of different fly ash levels on egg mass (EM) and reproduction factor (Rf) of *M. incognita* (Mi) and *M. javanica* (Mj) juveniles in pepper roots.

Experiment 26

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. incognita* on Okra Plant

Table 36 shows the effect of 20% level of fly ash together with different inoculum levels of *M. incognita*, on growth, yield and photosynthetic pigments of okra plant. All parameters of plant growth (length, fresh wt, dry wt of root and shoot, leaf number, leaf area), yield (flower/plant, fruit/plant) and photosynthetic pigments (chl.a, chl. b, total chl. a+b, carotenoids) were significantly (P=0.05 and P=0.01) increased in all the inoculum levels from 250 N to 5,000N compared to control set, except in 10,000N treatment, where all parameters were decreased significantly (P=0.05 and P=0.01). As the inoculum levels were increased, all the above parameters were gradually declined. Thus highest increment in all parameters were observed in 20% FA + 250N treatment (Fig. 29).

Experiment 27

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. javanica* on Okra Plant

The data summarized in table 37 also show that all growth, yield and photosynthetic parameters were increased significantly (P=0.05 and P=0.01) when okra was grown in 20% fly ash mixture alongwith different inoculum levels of *M. javanica* (from 250 to 5,000 juveniles) as in case of *M. incognita*. But as the inoculum level of *M. javanica* increased, all the

Table 36: Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of okra cv. Long Green.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ Plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	30.0	38.0	3.8	15.0	1.0	3.7	20	92	13	09	0.821	0.405	1.226	0.366
250 N	42.0	49.0	6.7	22.2	1.7	5.6	33	104	24	16	0.885	0.430	1.315	0.390
500 N	41.4	48.2	6.5	21.6	1.6	5.2	31	103	24	16	0.884	0.428	1.312	0.385
1,000 N	40.2	47.4	6.4	20.0	1.6	5.1	30	102	23	15	0.883	0.426	1.309	0.383
2,500 N	39.5	46.6	6.0	19.6	1.5	5.0	29	101	22	15	0.880	0.425	1.305	0.382
5,000 N	39.0	46.0	5.8	19.4	1.4	4.9	28	99	21	14	0.878	0.422	1.300	0.386
10,000 N	26.5	32.2	2.6	12.5	0.7	2.6	16	68	10	06	0.772	0.375	1.145	0.330
(P=0.05)	1.79	2.72	0.52	1.41	0.04	0.30	1.7	09	1.1	0.7	0.027	0.014	0.017	0.013
(P=0.01)	2.43	3.64	0.70	1.91	0.05	0.41	2.4	12	1.5	1.0	0.036	0.019	0.024	0.018

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

Table 37: Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of okra cv. Long Green.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	30.0	38.0	3.8	15.0	1.0	3.7	20	92	13	09	0.821	0.405	1.226	0.366
250 N	42.5	49.2	6.8	22.4	1.7	5.7	33	104	25	17	0.887	0.435	1.322	0.415
500 N	41.8	48.5	6.6	21.8	1.7	5.4	32	103	25	17	0.886	0.434	1.320	0.410
1,000 N	40.6	48.0	6.5	20.6	1.6	5.3	31	103	24	16	0.885	0.433	1.318	0.398
2,500 N	39.8	47.0	6.2	20.2	1.6	5.1	30	102	23	16	0.884	0.432	1.316	0.387
5,000 N	39.3	46.2	6.1	19.8	1.5	5.0	29	101	22	15	0.882	0.432	1.314	0.392
10,000 N	27.0	32.5	2.8	12.8	0.8	2.9	18	72	11	07	0.780	0.377	1.157	0.337
(P=0.05)	2.02	3.22	0.2	1.2	0.03	0.4	1.3	12	0.8	2.8	0.022	0.013	0.032	0.017
(P=0.01)	2.80	4.41	0.3	1.6	0.04	0.5	1.8	16	1.1	3.8	0.029	0.018	0.043	0.023

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

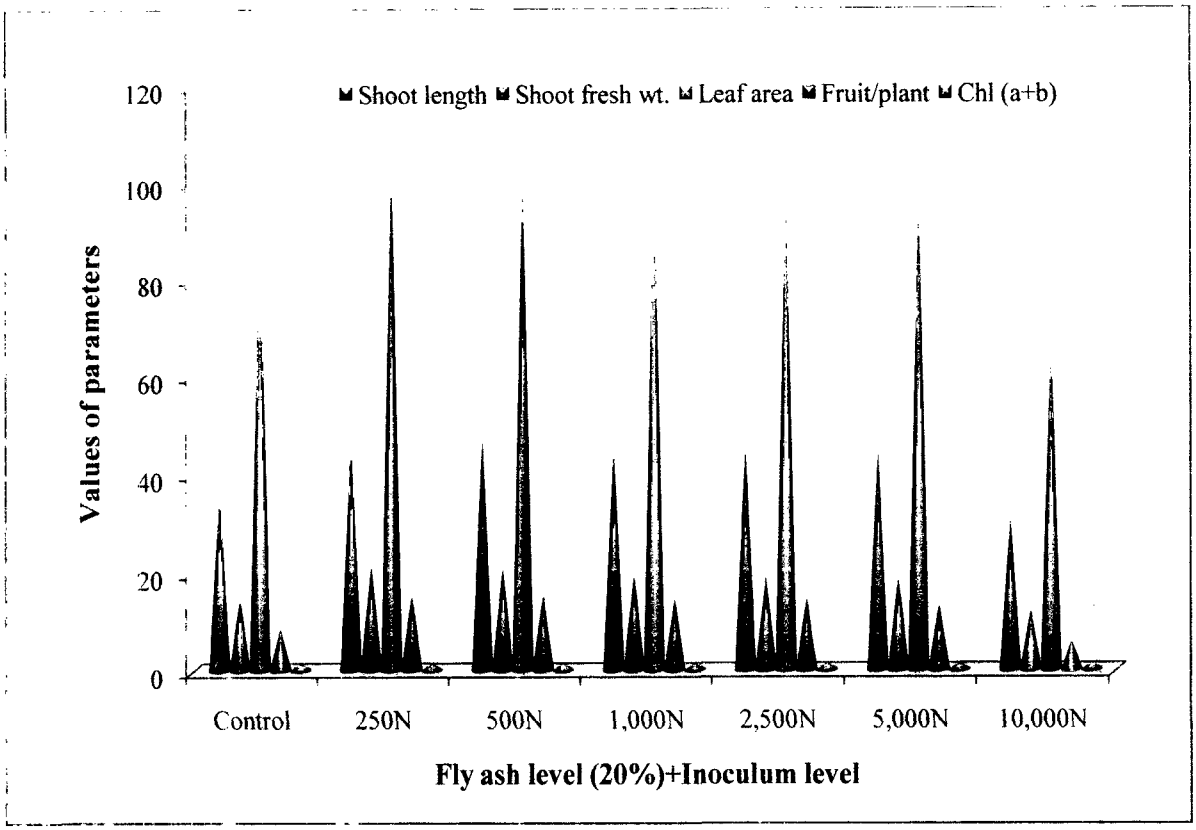


Fig.29: Effect of fly ash (20%) with different inoculum levels of *M. incognita* on okra.

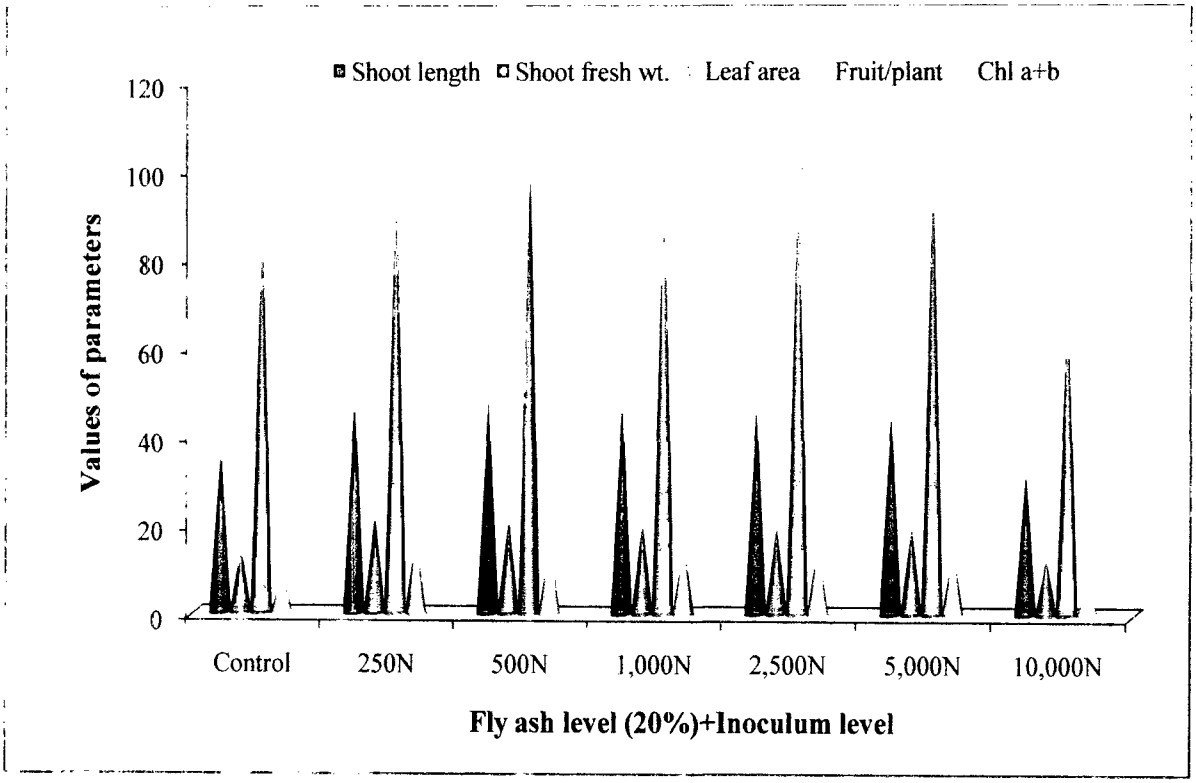


Fig.30: Effect of fly ash (20%) with different inoculum levels of *M. javanica* on okra.

above parameters decreased apparently. The best result was observed in 20% FA + 250N treatment. However, at highest inoculum level (10,000N) all these above parameters were significantly (P=0.05 and P=0.01) decreased (Fig. 30).

Experiment 28

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. incognita* on Cucumber Plant

The data given in table 38 reveal that 20% fly ash application together with *M. incognita* juveniles enhanced the plant growth (length, fresh wt, dry wt of root and shoot, leaf number, leaf area), yield (flower/plant, fruit/plant) and photosynthetic pigments (chl.a, chl. b, total chl. a+b, carotenoids) at all inoculum levels compared to control set, except 10,000N treatment, where, all parameters were decreased significantly (P=0.05 and P=0.01). As the inoculum level increased, all above parameters decreased apparently. The highest increment in these parameters was observed in 20% FA + 250N treatment (Fig. 31).

Experiment 29

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. javanica* on Cucumber Plant

Similar pattern of effect of 20% level with different inoculum levels of *M. javanica* (250, 500, 1000, 2500, 5000 and 10000N) was observed on all the growth, yield and photosynthetic pigments parameters of cucumber plant (Table 39). All parameters were increased significantly

Table 38: Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of cucumber cv. Poona Kheera.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ Plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	41.0	49.5	5.6	21.5	1.4	5.4	22	116	17	10	0.932	0.481	1.413	0.455
250 N	53.2	60.5	8.3	24.7	2.0	6.2	36	129	29	21	0.990	0.510	1.500	0.508
500 N	52.6	59.8	8.0	24.4	1.9	6.0	35	128	28	20	0.987	0.509	1.496	0.488
1,000 N	52.2	59.0	7.9	24.2	1.8	5.9	34	128	27	20	0.984	0.508	1.492	0.472
2,500 N	51.7	58.6	7.7	24.0	1.7	5.8	33	127	26	19	0.980	0.506	1.486	0.463
5,000 N	51.0	58.0	7.4	23.8	1.6	5.7	32	126	25	18	0.975	0.502	1.478	0.459
10,000 N	35.6	40.6	4.2	17.8	1.0	3.8	19	82	12	07	0.885	0.430	1.315	0.400
(P=0.05)	3.1	2.4	0.72	2.17	0.2	0.31	0.93	7.2	2.5	1.4	0.025	0.016	0.033	0.031
(P=0.01)	4.2	3.2	0.98	2.96	0.3	0.42	1.27	9.8	3.4	1.9	0.034	0.022	0.045	0.042

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

Table 39: Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of cucumber cv. Poona Kheera.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ Plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	41.0	49.5	5.6	21.5	1.4	5.4	22	116	17	10	0.932	0.481	1.413	0.455
250 N	53.2	60.6	8.4	24.8	2.1	6.2	36	130	30	22	0.990	0.512	1.502	0.510
500 N	52.8	60.1	8.2	24.6	2.0	6.1	35	129	29	21	0.989	0.511	1.498	0.508
1,000 N	52.4	59.6	8.1	24.4	1.9	6.0	35	129	29	21	0.986	0.510	1.496	0.506
2,500 N	52.0	59.0	8.0	24.3	1.8	5.9	34	128	28	20	0.985	0.509	1.492	0.504
5,000 N	51.7	58.3	7.6	24.0	1.7	5.8	33	127	27	19	0.980	0.508	1.488	0.501
10,000 N	36.0	41.2	4.5	18.2	1.1	4.0	20	85	13	08	0.892	0.435	1.327	0.424
(P=0.05)	1.75	2.06	0.72	0.91	0.03	0.2	0.79	7.9	2.19	9.2	0.018	0.016	0.028	0.012
(P=0.01)	2.37	2.79	0.98	1.18	0.04	0.3	1.07	10.7	3.31	1. 2	0.025	0.022	0.038	0.016

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

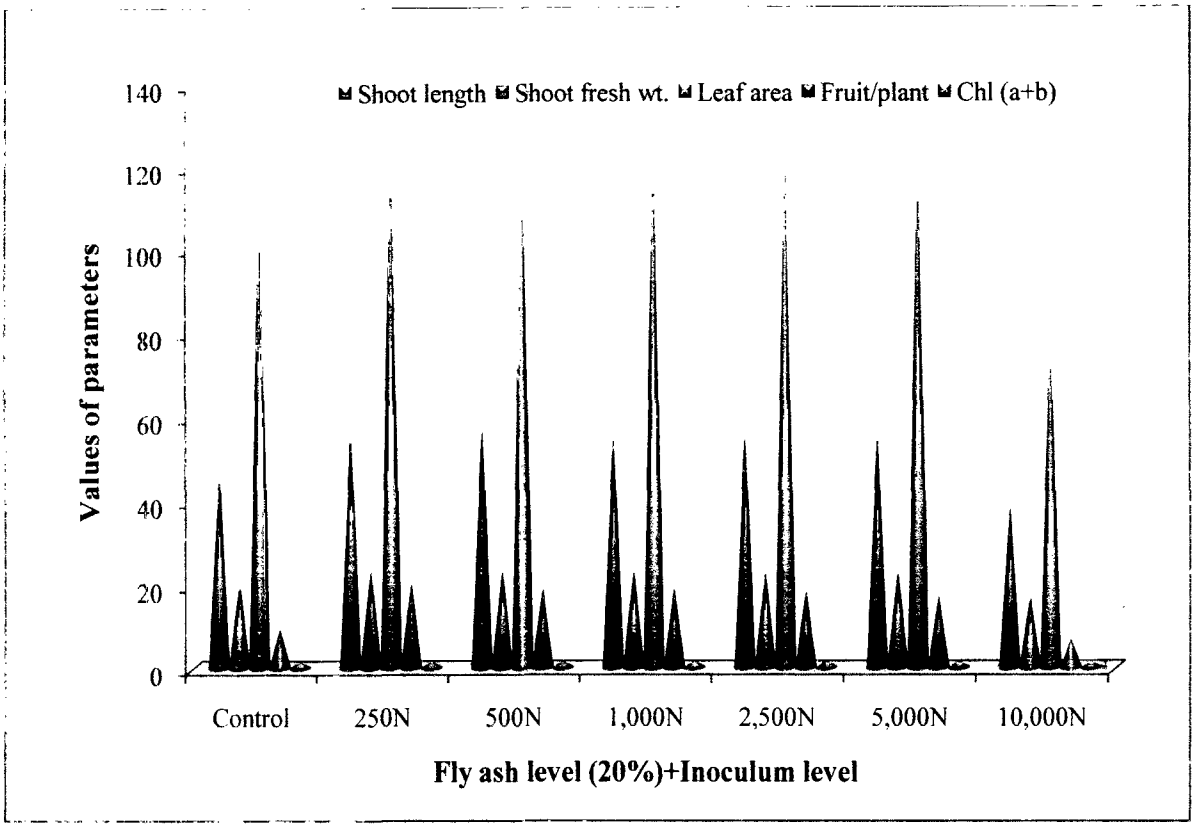


Fig.31: Effect of fly ash (20%) with different inoculum levels of *M. incognita* on cucumber.

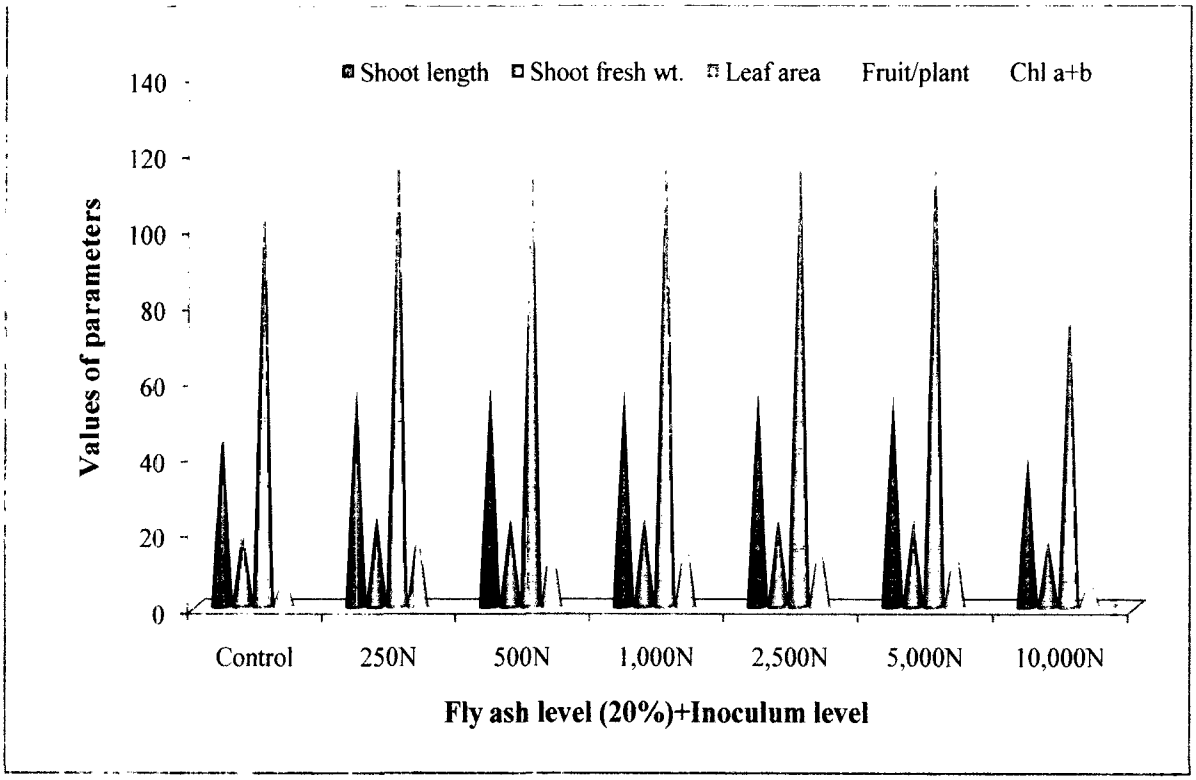


Fig.32: Effect of fly ash (20%) with different inoculum levels of *M. javanica* on cucumber.

(P=0.05 and P=0.01) upto 5000N inoculum level. The highest increase in the parameters was observed in 20% FA + 250N treatment. However, in 20% FA + 10,000N treatment a significant (P=0.05 and P=0.01) reduction was recorded in all the parameters (Table 39 and Fig. 32).

Experiment 30

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. incognita* on Pepper Plant

From the table 40, it appears that the 20% level of fly ash alongwith different inoculum levels of *M. incognita* (250, 5000, 1000, 2500, 5000 and 10000N) improved the plant growth, yield and photosynthetic pigments significantly (P=0.05 and P=0.01) compared to control set, except at 20% FA + 10,000N treatment. The maximum improvement was observed at 20% FA + 250N treatment (Fig. 33). As the level of *M. incognita* juveniles increased, all above parameters gradually decreased. However, at 10,000N inoculum level all the parameters reduced significantly (P=0.05 and P=0.01).

Experiment 31

Effect of Fly Ash (20%) with Different Inoculum Levels of *M. javanica* on Pepper Plant

In table 41 data indicate that all plant growth, yield and photosynthetic pigments were significantly (P=0.05 and P=0.01) increased in all treatments compared to control, except in treatment 20% FA + 10,000N. The highest increment in these parameters were found in

Table 40: Effect of 20% level of fly ash with different inoculum levels of *M. incognita* on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ Plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	16.7	30.9	3.0	8.9	0.8	2.3	69	17	07	05	0.757	0.386	1.143	0.349
250 N	26.8	41.9	5.4	11.7	1.4	2.9	87	27	17	13	0.828	0.402	1.230	0.366
500 N	26.6	41.7	5.3	11.6	1.3	2.8	86	26	16	12	0.823	0.400	1.222	0.363
1,000 N	26.4	41.5	5.1	11.4	1.2	2.7	85	26	15	11	0.816	0.397	1.216	0.362
2,500 N	26.2	41.3	4.9	11.2	1.1	2.6	84	25	14	10	0.812	0.394	1.208	0.358
5,000 N	26.0	39.8	4.7	11.0	0.9	2.5	83	22	13	09	0.808	0.389	1.197	0.355
10,000 N	14.6	25.2	2.2	7.0	0.5	1.6	56	13	04	00	0.686	0.320	1.006	0.283
(P=0.05)	0.77	2.16	0.52	0.93	0.06	0.2	6.21	2.11	0.73	2.1	0.031	0.007	0.025	0.008
(P=0.01)	1.01	2.93	0.71	1.26	0.09	0.3	9.15	2.92	1.01	2.8	0.042	0.010	0.034	0.011

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

Table 41: Effect of 20% level of fly ash with different inoculum levels of *M. javanica* on plant growth performance, yield and photosynthetic pigments of pepper cv. Suryamukhi Green.

FA (20%) + Inoculum level	Plant growth								Yield		Chlorophyll			Cart.
	Length (cm)		Fresh wt (g)		Dry wt (g)		Leaf/ plant	Leaf area (cm^2)	Flower $Plant^{-1}$	Fruit/ plant	Chl.a	Chl.b	Total (a+b)	
	Root	Shoot	Root	Shoot	Root	Shoot					(mg g^{-1} leaf fresh wt)			
Control	16.7	30.9	3.0	8.9	0.8	2.3	69	17	07	05	0.757	0.386	1.143	0.349
250 N	27.0	42.0	5.4	11.8	1.4	3.0	88	28	18	14	0.830	0.405	1.235	0.370
500 N	26.9	41.8	5.3	11.7	1.3	2.9	87	27	17	13	0.828	0.402	1.232	0.368
1,000 N	26.8	41.6	5.2	11.6	1.2	2.8	86	26	16	12	0.826	0.400	1.228	0.366
2,500 N	26.7	41.4	5.1	11.4	1.1	2.7	85	25	15	11	0.823	0.398	1.222	0.363
5,000 N	26.4	41.0	4.9	11.2	1.0	2.6	84	24	14	10	0.820	0.396	1.216	0.360
10,000 N	15.0	25.6	2.4	7.1	0.6	1.7	60	14	05	00	0.690	0.328	1.018	0.291
(P=0.05)	0.61	2.23	0.42	0.3	0.09	0.2	4.1	1.21	0.9	0.3	0.022	0.009	0.025	0.008
(P=0.01)	0.97	3.16	0.57	0.4	0.13	0.3	5.9	1.63	1.2	0.4	0.030	0.012	0.035	0.011

Each value is a mean of five replicates. FA = Fly ash; N = Nematode; Cart. = Carotenoids.

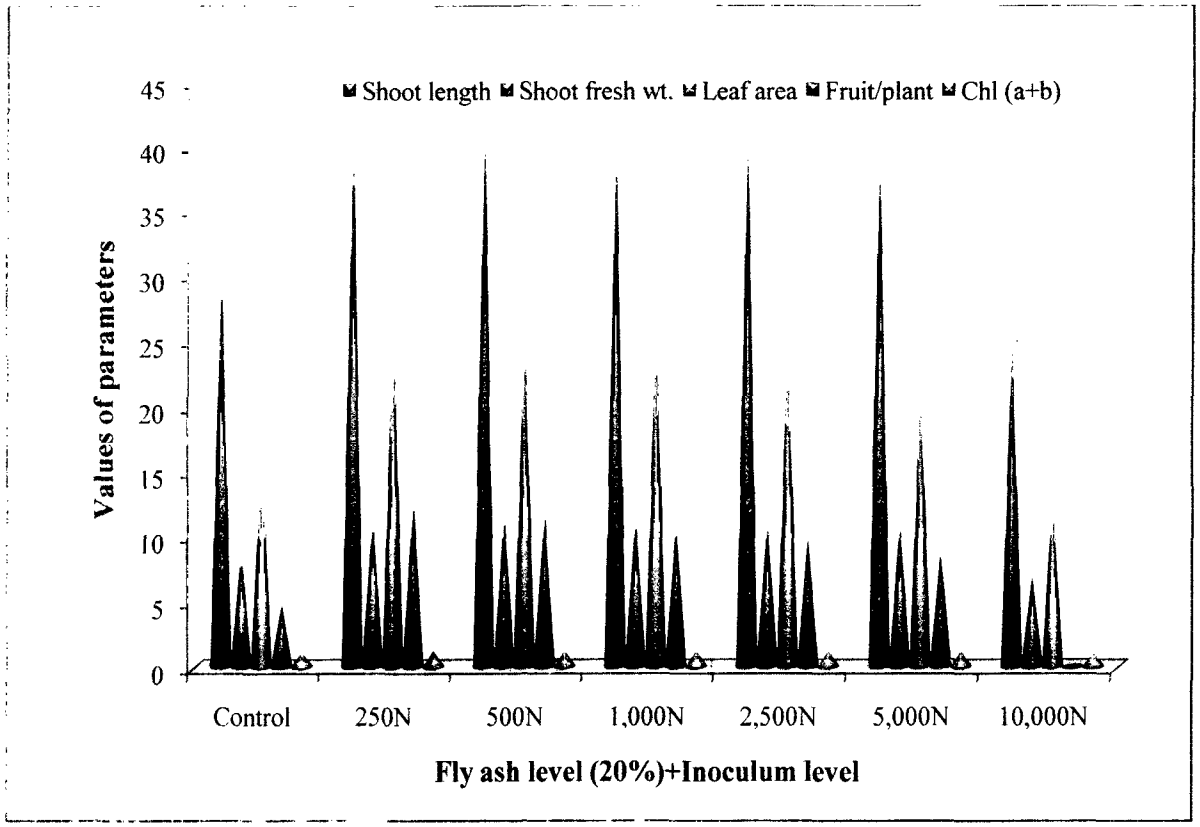


Fig.33: Effect of fly ash (20%) with different inoculum levels of *M. incognita* on pepper.

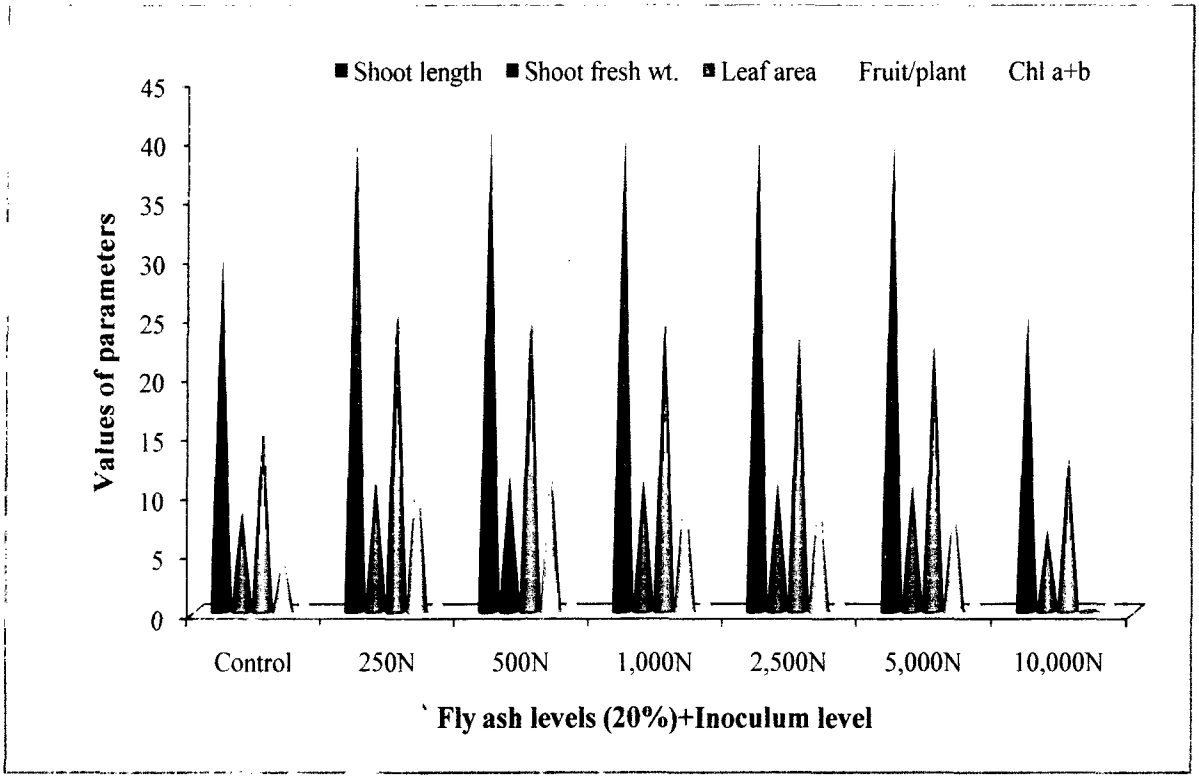


Fig.34: Effect of fly ash (20%) with different inoculum levels of *M. javanica* on pepper.

20% fly ash with lower inoculum level (250N). As the inoculum level increased, all these parameters decreased gradually (Fig. 34). However, significant reduction was observed with higher inoculum level (10,000N).

DISCUSSION

Fly ash is one of the residues generated in the combustion of coal at very high temperature, 1200-1400°C in Thermal Power Plants. A huge amount (100 million tons) of fly ash is released annually through the Thermal Power Plants in India. Although, fly ash is considered as particulate air pollutant, however, in recent years, it is used in field for production of crop, as it contains various utilizable plant nutrient elements such as Ca, Mg, Fe, Cu, Zn, K, Mn, B, S and P (Adriano *et al.*,1980; Fulekar *et al.*, 1983; Majumdar and Mukherji, 1983; Dalmau *et al.*, 1990; Sikka *et al.*, 1994). The response of plants to micro and macro nutrients in fly ash may vary from beneficial effects of small concentrations of nutrient element to toxic effects of high concentrations. In the present study, it was attempted to evaluate the potential of fly ash to manage the root-knot nematodes on three vegetable crops- okra, cucumber and pepper.

Root-knot nematodes are the most damaging pathogens to the plants especially vegetable crops throughout the world. About 2000 plants are susceptible to infection by one or the other species of root-knot nematodes and they cause approximately 5% of global crop loss (Sasser and Carter, 1985). Vegetables, horticultural and field crops are greatly suffered due to *Meloidogyne* species in India. So far 11 species have been reported from all over the country (Sitaramaiah, 1984; Krishnappa, 1985; Khan, 2007). Since the use of nematicides was banned, the eco-friendly

control measures have been suggested to manage the nematodes. In the present study the use of fly ash was a step towards management of the root-knot nematodes on some vegetable crops (okra, cucumber and pepper), as it has shown its potential to kill the nematodes (Singh, 1989; Singh, 1993; Khan, 2007).

SECTION-I (SURVEY AND ANALYSIS)

In the present study, a systematic survey was conducted to assess the incidence and intensity of root-knot disease and to identify the species associated with vegetable crops in order to understand their pattern of distribution in Western Uttar Pradesh. Five districts namely Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar were selected as study area. Disease incidence and intensity were determined for each district and vegetable crop. Results obtained showed that overall incidence of the disease in the area was very high. About 51.51% root samples were infected with root-knot nematodes. The incidence of disease in the vegetable field was highest in Aligarh (56.57%) and lowest in Gautam Buddha Nagar (47.89%). On the vegetables the incidence of the disease was highest on eggplant (66.96%) and lowest on cabbage (18.18%) (Table 6). The intensity of disease in terms of gall index and egg mass index was also very high (1-5/0-5) in the area. Variation in incidence and intensity of the disease were, however, noticed locality-wise, district-wise or vegetable-wise. Apparently root-knot nematodes are fairly widely distributed in the area

and infesting a high percentage of vegetable field. Sufficient root galling and egg mass production recorded on crops. The adverse effect on crop productivity and ensure high population build up which may endanger for the vegetable crops, because vegetables are recognized as most commonly attacked group of crops by root-knot nematodes (Lamberti, 1979; Sasser, 1979). Sasser (1979) who reviewed the distribution, pathogencity and relative importance of *Meloidogyne* spp in the tropics expressed that from the data available there was little doubt that crop losses were very large. In his review, estimated percent loss due to root-knot nematodes for vegetables ranged from 15 to 30%. He remarked that potential for damage caused by root-knot nematodes is ever present in the tropics. Present investigation also confirms the high percentage of loss in the surveyed fields, as India is a tropical country. Similar results have also been obtained by Khan and Khan (1990, 1991a, 1993) and Khan (2007). Present study clearly demonstrates a high incidence and intensity of disease on major vegetables (okra, cucumber and pepper) grown in India. The wide occurrence of root-knot disease and level of infestation would certainly be reflecting in the productivity of crop grown in the area. This fact should be taken into account in the disease management strategies of the vegetable crops for the area.

Three species of root-knot nematodes, *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in vegetable fields of Western Uttar Pradesh. Frequency of occurrence of *M. incognita* (47.32%) was highest closely followed by *M. javanica* (40.98%).The

frequency of *M. arenaria* was lowest (11.71%). Highest frequency of *M. incognita* has also been observed all over the world (Sasser, 1979; Lamberti, 1979; Sasser and Carter, 1985; Eisenback and Triantaphyllou, 1991; Khan, 2007). The *M. javanica* and *M. arenaria* occupied second and third position respectively in the present study. Thus *M. incognita* dominates over the *M. javanica* and *M. arenaria* in the study area. Similar positions have also been reported by Sasser and Carter (1985) through International *Meloidogyne* Project. However, sometime, the frequency of one species is higher than other at one place and vice versa at another place. For example in Gautam Buddha Nagar the frequency of *M. javanica* (47.06%) was higher than *M. incognita* (38.24%) and *M. arenaria* (14.71%). Present findings also confirm the reports of Sitaramaiah (1984), Krishnappa (1985), Khan and Khan (1990, 1991a, 1993) and Khan (2007) from various parts of India.

Application of fly ash changed the physico-chemical properties of soil. The pH, electrical conductivity, cation exchange capacity and water holding capacity were increased gradually as levels of fly ash were increased in soil. The rise in pH actually depends primarily on soil buffering capacity. The increased pH was also observed in many studies when fly ash levels were increased gradually (Page *et al.*, 1979; Menon *et al.*, 1990; Khan and Khan, 1996; Tripathy and Sahu, 1997; Brahamachari *et al.*, 1999). The rise in electrical conductivity and cation exchange capacity might be due to the increasing inorganic constituents in the fly ash. Improvement in soil electrical conductivity and cation exchange

capacity due to fly ash addition has also been observed by Deshmukh *et al.* (2000). Thus above results also confirm the present findings of increment of electrical conductivity and cation exchange capacity due to addition of fly ash to soil.

The results of the present study reveal that fly ash application to soil increased the water holding capacity with increasing levels of fly ash. Upadhyay (2002) and Raghav (2006) also found the significant increasement in water holding capacity as the level of fly ash increased. Contents of sulphur and chloride were increased in all the levels of fly ash in this study. Khan *et al.* (1997) also found same trend of increment in the contents of sulphate and chloride.

The present study shows that available nitrogen is very low (12 mg/kg) in fly ash compared to soil (93 mg/kg). From the literature, it appears that nitrogen is absent in fly ash (Khan and Khan 1996; Singh *et al.*, 1997; Khan *et al.*, 1997) or in little amount (Bhattacharya and Chattopadhyay, 2002). Thus, by increasing the levels of fly ash caused deficiency of nitrogen in soil. Bradshaw and Chadwick (1980) also suggested that fly ash contains little to no nitrogen because the nitrogen originally present in coal is volatized during combustion.

The levels of available phosphorus and potassium increased gradually in soils as levels of fly ash increased. This might be due to presence of these elements in fly ash in sufficient quantity. Similar trend of increase of these elements in fly ash amended soils were observed by

Hammermeister *et al.* (1998), Khan and Khan (1996), Upadhyay (2002) and Raghav (2006). This is attributed the improvement in the soil physical and chemical properties as opened by Epstein *et al.* (1996) who asserted that the most important function of non conventional fertilizer in the field are increasing cation exchange capacity, improving soil structure through mineralization provision of nutrients.

SECTION-II (FLY ASH EFFECT ON RKN)

In the present study, fly ash-extract was tested against root-knot nematodes, *M. incognita* and *M. javanica*. The observations showed that all the fly ash-extract levels inhibited the hatching of *M. incognita* and *M. javanica*. This might be due to presence of some toxic constituents and changes in pH level (Helder *et al.*, 1982; Khan, 2007) which were harmful to these nematodes. Similar results were also obtained earlier by Tarannum *et al.* (2001) and Iram (2006) on *M. javanica* and *M. incognita* Race 1 respectively. Rizvi (2008) also observed the inhibition in hatching of *M. javanica* juveniles when exposed to fly ash and brick kiln dust-extracts levels. Present study also showed the variations in responses of nematodes to the extract. The hatching was slightly more in *M. incognita* as compared to *M. javanica*. Perhaps, the effect of fly ash-extract was slightly less on *M incognita* as compared to *M. javanica*. In another word, it can be said that *M. incognita* has slightly tolerance as compared to *M. javanica*. That is why the population of *M. incognita* is found more in the world (Sasser, 1979; Lamberti, 1979). In the present study all the levels

of fly ash-extract were found harmful to both the nematodes. However, effect was slightly more on *M. javanica* than *M. incognita.*

The rate of the juveniles mortality was directly proportional to concentration and time intervals. This might be due to presence of toxic compounds i.e. dibenzofuron, dibenzo-p-dioxine and sulphur and chlorides (Helder *et al.*, 1982). The rise in pH (9.18) level also may be one of the reasons for mortality. Similar results were observed by Singh (1989) in *M. incognita.* Recently, Kausar (2007) has also reported the harmful effect of fly ash-extract on juveniles mortality of seed gall nematode (*Anguina tritici*). Rizvi and Khan (2009) have also observed the mortality of *M. javanica* in different levels of fly ash and brick kiln dust-extracts.

The penetration of juveniles of *M. incognita* and *M. javanica* in the roots of okra, cucumber and pepper were suppressed greatly under the influence of fly ash amended soils. As the levels of fly ash increased the penetration was decreased. This might be due to toxic effect of fly ash to nematodes. Similar results have also been observed by Tarannum *et al.* (2001) on *M. javanica* in chickpea roots and by Rizvi (2008) in brinjal roots. Edongali *et al.* (1982) stated that juveniles penetration is affected by the concentration of the different elements, perhaps the type of element in the soil solution.

Juveniles penetration in the present study was slightly greater in okra root followed by cucumber and pepper roots by both nematodes

regardless of treatments. This might be due to difference in their degree of susceptibility to the nematodes. This shows that okra was most suitable host followed by cucumber and pepper. Among the juveniles, the *M. incognita* juveniles penetrated slightly greater in number than *M. javanica* in the roots of all three crops. Perhaps, reason is the same as discussed earlier in hatching portion.

The subsequent development of juveniles of *M. incognita* and *M. javanica* were suppressed and delayed in roots of all the above three crops. All the ratios of fly ash were harmful for the development of the juveniles. This might be due to toxic effect of fly ash to nematodes. These results are similar to those of Tarannum *et al.* (2001) on *M. javanica* in chickpea roots, Rizvi (2008) on *M. javanica* in brinjal roots and Azam *et al.* (2007) on *M. incognita* in ivy gourd roots (*Coccinia cordifolia*). At first week less juveniles penetrated, whereas at second, third and fourth weeks more juveniles penetrated the roots but their numbers were always less than control. This difference in numbers was concentration dependent, with an increase in the concentration, there was a corresponding decrease in number of females at all the time intervals in each treatment (Table 18-23). The higher concentration was more effective and the degree of suppression varied with the type of plant and nematode species. The penetration and post-penetration development of both nematodes were greatly affected. In general, it was observed that some penetrated juveniles were still in different stages of development even after four weeks irrespective of treatments and crops (Table 18-23).

However, number of juveniles of any stage were greater in number in okra followed by cucumber and pepper. This variation might be attributed to the difference in their degree of susceptibility to the nematode. These results are similar to those of Edongali *et al.* (1982). In the present study, it was also observed that all the developed stages of *M. incognita* juveniles were slightly greater in number than *M. javanica* in roots of all three crops in all the treatments. This difference might be due to invading capability or tolerant nature of *M. incognita* to stresses as advocated by Khan (1988).

SECTION-III (EFFECT OF FLY ASH ON PLANT AND RKN)

Incorporation of fly ash in agricultural fields for improvement of crop is a very recent idea. Some studies and data available indicate that it can serve as a fertilizer, as it enhances plant growth and productivity (Wong and Wong, 1989; Sikka and Kansal, 1995; Kalra *et al.*, 1998). A number of crops are being examined for their responses to fly ash in relation to growth and productivity and tolerance of fly ash levels to soil.

In the present study the lower levels (5 to 30%) of fly ash were found beneficial for all the three vegetable crops (okra, cucumber and pepper). The 20% level of fly ash was found most effective for plant growth (length, fresh wt. and dry wt. of root and shoot, leaf area, leaf/ plant) and yield (flower/plant, fruit/plant). This might be due to changes that occurred in structure of fly ash amended soil and presence of sufficient nutrients at this level which was suitable for the growth of all

the three vegetable crops. Similar beneficial effects on above parameters at lower levels have also been observed on a number of crops like *Brassica juncea*, cabbage, *Linum usitatissimum*, groundnut, *Lactuca sativa*, lentil, potato, bottle gourd, maize, rice, wheat etc. (Singh and Singh, 1986 b; Singh, 1989; Kulshreshtha, 1995; Sikka and Kansal, 1995; Upadhyay, 2002; Upadhyay and Khan, 2002; Raghav and Khan, 2002; Raghav, 2006; Kausar, 2007).

However, the responses of different crops were different to various levels of fly ash (10-50%). For example the better growth and yield of chickpea was obtained at 40% fly ash by Siddiqui *et al.* (2000). The highest yield of soyabean was obtained in the treatment receiving 10% (w/w) fly ash (Lal *et al.*, 1996). Soil with 20% fly ash amendment improved the dry matter and yield of collard greens and mustard green crops (Menon *et al.*, 1990). Sarangi and Mishra (1998) found that 15% fly ash as an appropriate level for groundnut, ladyfinger and radish. Rengifo *et al.* (1996) showed that 20% level of fly ash was best for the improvement of *Capsicum* and tomato. Sahu and Dwivedi (1999) reported that 25% fly ash was useful for *Vigna mungo* and 50% for okra. Srivastava *et al.* (1995) observed that lower level (10%) gave the greatest root and shoot length, number of leaves, leaf area, root weight, root: shoot ratio and leaf carotenoid and chlorophyll a and b contents of *Lactuca sativa* crop. Pandey *et al.* (1994) also observed that leaf number, leaf area, flower weight and plant height of sunflower crop were increased in 60 days old plants when fly ash was amended by 0.5 Kg fly ash/m^2.

Azam *et al.* (2007) observed that the length, fresh wt and dry wt of the *Coccinia cordifolia* plant were increased in 30% fly ash. Recently, Rizvi and Khan (2009) found that 20% level of fly ash was ideal level for the better plant growth and yield of eggplant.

In the present study, higher levels (onwards 40%) were found harmful to plant growth and yield of all the three crops (okra, cucumber and pepper). This shows that the available nutrients present in fly ash were beneficial at certain levels for utilization of a particular plant species. Higher levels adversely affected the plant growth and other parameters of these vegetable crops. The adverse effects of fly ash at higher levels of application are attributed to excess of micro nutrients (Adriano *et al.*, 1980) and toxicity of compounds like dibenzofuran, dibenzo-p-dioxine and metals found in fly ash (Helder *et al.*, 1982; Mishra and Shukla, 1986; Wong and Wong, 1986). The higher levels of fly ash, more than 50% were found harmful to all the crops examined so far in the studies done by the investigators, as on *Brassica juncea*, chickpea, cucumber, lentil, *Linum usitatissimum*, maize, potato, soybean, tomato and wheat (Mishra and Shukla, 1986; Pasha *et al.*, 1990; Singh, 1993; Raghav and Khan, 2002; Upadhyay and Khan, 2002; Raghav, 2006; Kausar, 2007). Kene *et al.* (1991) observed that fly ash onwards 60 % in soil had negative effect on growth and yield performance of sunflower crop over control. Singh (1993) also observed negative effect of fly ash on soybean at higher level (50% to 100%). Khan and Khan (1994) reported the harmful effect of higher level of fly ash (more than

40%) on tomato. Similarly in the present study, onwards 40% levels, there was gradual reduction in plant growth and yield. These results showed that the available nutrients present in fly ash were beneficial at certain levels for a particular plant. This might be due to the genetic make up of crop, which has its tolerance limit at this level. After that absorbed elements acted as phyto-toxic elements and thus retarded the growth and yield of crop gradually as levels were increased.

Photosynthetic pigments (Chl a, Chl b, Chl a+b, carotenoids) were increased gradually upto 30% level of fly ash, highest being at 20% level, after that pigments were declined in the present study. Photosynthetic pigments were also found high at lower levels of fly ash in chickpea, cucumber, lentil, pea, soybean, tomato, wheat etc. (Singh, 1989; Pasha *et al.*, 1990; Singh, 1993; Khan *et al.*, 1997; Kulshreshtra, 1995; Kausar, 2007). At 20% level, the plant produced healthy and greater number of leaves, which were darker than leaves of other levels. The photosynthetic activity of these crops might have enhanced at this amendment level resulting better growth and productivity due to high chlorophyll contents. Kleinkopt *et al.* (1976) also advocated that any change in efficiency of photosynthetic machinery ultimately affects the amount of photosynthates, which steers the growth of the plant. The higher levels of fly ash were harmful to photosynthetic pigments in the present study. In corn and soybean Mishra and Shukla (1986) also observed that higher levels of fly ash reduced the metabolic and amount of photosynthetic pigments. Similar results were also observed by Pasha *et al.* (1990) on

photosynthetic pigments in cucumber. Singh (1993) concluded that higher concentrations of substrate salt and trace elements at higher levels of fly ash generally reduce photosynthesis.

In fly ash + nematode inoculated treatments, the growth responses of all the three crops (okra, cucumber and pepper) were significantly much better than the nematode alone inoculated set. This shows that fly ash interacted antagonistically with nematodes and was able to check the infection that became beneficial for the crops. This might be due to excess of salts, toxic compounds and heavy metals (Helder *et al.*, 1982) which caused nematicidal effects on nematodes either directly or within the host. The development of galls, egg mass production and reproduction were completely checked onward 20% levels in all the three crops. Nematodes might have lost their activities and later could not survive under the stress of fly ash. Similar pattern was also observed by Siddiqui and Singh (2005). They observed that fly ash treatments adversely affected root invasion by juveniles, disease intensity and reproduction of the nematodes and the most effective level was 40% for pea plants. However, plant growth and yield in combined treatments were slightly less than their respective fly ash amended soil treatments without nematodes. This might be due to some damage caused by fresh nematodes before becoming inactive due to fly ash.

The different inoculum levels of nematodes (250; 500; 1000; 2500 and 10,000) with 20% level of fly ash also affected variably to growth,

yield and photosynthetic pigments of all the three crops. Perhaps, nematodes also affected the crops with respect to their inoculum levels, because before loosing their activity they could cause little damage to plants. But this was nematode inoculum dependent. Similar results have also obtained by Kausar (2007) with *Anguina tritici*. In this study 20% level was found the best level of fly ash to all three crops, even in presence of nematodes. All parameters were found highest with this dose and low inoculum level (20% fly ash + 250N) compared to control or any combination of nematode. Because this dose was effective enough to kill the nematodes. Inhibition in penetration and not reaching to mature stage of juveniles are very important for the agriculture point of view, because there will be no loss to crops. So, it can be summarized that 20% fly ash is the best dose for these crops. Because this dose is increasing the growth and productivity of plants and also managing the root-knot nematodes.

CONCLUSION

The study clearly demonstrated that root-knot nematodes are a major problem of vegetable crops in Western Uttar Pradesh. After survey, two species, *M. incognita* and *M. javanica* were found to be more common and more frequent than other species (*M. arenaria*) in this area. The survey indicates that root-knot nematodes are greatly affecting plant growth of vegetables and causing appreciable yield losses. Fly ash has shown good source of nutrient elements which are beneficial to plants. The soil application of fly ash ameliorated plant growth of three vegetables (okra, cucumber and pepper) and suppressed the nematode penetration and delayed the development. Soil application of fly ash from 10 to 30% levels was found beneficial for all the three crops, maximum being at 20% level.

Nematode inoculated plants also showed improvement in their plant and yield under the influence of fly ash. At the same time, development of galls, egg masses and reproduction were completely checked. Fly ash and nematodes together interacted antagonistically. The study showed that fly ash was beneficial to the plants at lower level (20%) and toxic to root-knot nematodes at all the levels. Thus fly ash can be used as an eco-friendly nematicide-cum-nonconventional fertilizer at 20% level. Use of fly ash in the agricultural field will improve the fertility of soil which would be beneficial to crops. On the other hand it has enough potential to manage the nematodes, and at the same time, it can

solve the disposal problem of huge amount of fly ash generated daily. Thus use of fly ash as soil amendment can be recommended to farmers for the management of root-knot nematodes in the vegetable fields.

SUMMARY

SECTION-I

Surveys were conducted for root-knot nematodes in some localities of 5 selected districts (Aligarh, Bulandshahr, Gautam Buddha Nagar, Ghaziabad and Mahamaya Nagar) of Western Uttar Pradesh. Highest incidence and intensity of root-knot disease was found in the vegetable fields of Aligarh district followed by Bulandshahr, Ghaziabad, Mahamaya Nagar and Gautam Buddha Nagar. Similarly, incidence and intensity of disease was also observed on different vegetables. Highest incidence and intensity was noticed on eggplant followed by tomato, okra, pepper, cucumber and cabbage. Three species- *M. incognita*, *M. javanica* and *M. arenaria* were identified to be present in the area. In these three identified species *M. incognita* and *M. javanica* were common and more frequent than *M. arenaria*. Disease intensity in terms of Gall index and egg mass index (EMI) was maximum in case of *M. incognita* and minimum in *M. arenaria*. The survey indicates that root-knot nematodes would affect the plant growth and can cause appreciable yield losses to vegetables, if suitable step will not be taken.

Application of fly ash to soil (0, 5, 10, 20, 30, 40, 50, 75 and 100% levels) changed the physico-chemical properties of the soil. The physico-chemical properties viz. pH, EC, CEC, WHC, sulphate, chloride, phosphorus and potassium were increased gradually and significantly

with the increasing levels of fly ash. While nitrogen was decreased gradually with the increasing levels of fly ash.

SECTION-II

All the levels of fly ash-extract (5, 10, 20, 30, 40, 50, 75 and 100%) significantly suppressed the hatching of *M. incognita* and *M. javanica* juveniles. Inhibition (%) in hatching of juveniles was directly proportional to the levels of fly ash-extract. As the level of fly ash increased, inhibition in hatching of both the juveniles was also increased. Similarly, all the levels of fly ash-extract were harmful to juveniles of both the nematodes. All the above levels of fly ash-extract killed the juveniles of both the nematodes. The mortality (%) was directly proportional to concentration as well as number of days increased. However, inhibition (%) in hatching and mortality (%) of juveniles was greater in *M. javanica* as compared to *M. incognita.*

Penetration of juveniles was retarded at all the levels of fly ash in roots of all the three crops (okra, cucumber and pepper). Penetration of the juveniles of both the nematodes was inversely proportion to the fly ash ratio. As the levels of the fly ash were increased, less number of juveniles of *M. incognita* and *M. javanica* were penetrated. Similarly, development of juveniles of both the nematodes was delayed and suppressed at all the levels of fly ash. At last, in fourth week none of the juveniles reached to mature female stage except at 5-10% fly ash levels. However, effect of fly ash was slightly more on *M. javanica* than *M.*

incognita. Root penetration and their subsequent development were greater in okra followed by cucumber and pepper roots.

SECTION-III

Soil application of fly ash was found beneficial to all the three crops (okra. cucumber and pepper). All parameters were increased significantly up to 30% levels of fly ash, maximum being at 20% level in all the crops.

Nematode inoculated plants also showed improvement in their plant growth, yield and photosynthetic pigments under the influence of fly ash. However, in combined treatments all parameters were increased significantly from 10 to 30% levels, highest being at 20% level + nematode combination. While at 40% level, all the parameters were at par in single fly ash amended treatment or in combination with any nematode, on any crop. In rest of the combinations, nematodes effects were suppressed completely. So from 50 to 100% fly ash amended soil + nematode showed similar results as single fly ash amended treatments, however growth was slightly less than fly ash amended soil without nematode.

At the same time, development of galls, egg masses and reproduction were completely checked. Fly ash and nematodes together interacted antagonistically. The study showed that fly ash was best to the plant growth and productivity at lower level (20%) and toxic to root-knot nematodes at all the levels.

Best dose of fly ash (20%) together with different inoculum levels of nematodes (250; 500; 1,000; 2,500; 5,000 and 10,000), affected variably to growth, yield and photosynthetic pigments of all the three crops. All parameters were significantly decreased as the inoculum level increased. All parameters were found highest with best dose and low inoculum level (20% fly ash + 250 N) compared to control set. However, this dose was effective enough to kill the nematodes except in plant inoculated with highest level (10,000), where some individuals of root-knot nematodes were able to slightly affect the plant growth, yield and photosynthetic pigments. However, none of the galls or egg mass was produced. So, it can be summarized that 20% fly ash is the best dose for these crops. Because this dose is increasing the growth of plants and also managing the root-knot nematodes.

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